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TESIS DOCTORAL

Amplificadores de Banda Ancha y Bajo Ruido Basados en Tecnología de GaAs para Aplicaciones de Radiometría

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Publicaciones relacionadas con la Tesis

Revistas Internacionales

1. B. Aja, M.L de la Fuente, J.P. Pascual, M. Detratti, E. Artal., “GaAs PHEMT Broadband Low Noise Amplifier for Millimeter Wave Radiometer”, *Microwave and Optical Technology Letters (Wiley Periodicals, Inc)*, Vol. 39, Issue 6, pp. 475-479, Dec. 2003
2. J.P. Pascual, B. Aja, M.L. de la Fuente, M. Detratti and E. Artal., “Equalize Gain In Millimeter-Wave Amplifiers”, *Microwave & RF*, Vol. 44, Issue 4, pp. 61-68, Apr. 2005
3. Beatriz Aja, Eduardo Artal, Luisa de la Fuente, Juan Pablo Pascual, Angel Mediavilla, Neil Roddis, Danielle Kettle, W. Frank Winder, Lluis Pradell i Cara, and Pedro de Paco, “Very Low-Noise Differential Radiometer at 30 GHz for the PLANCK LFI”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, Issue 6, pp. 2050-2062, Jun. 2005
4. M. Bersanelli, B. Aja, E. Artal, M. Balasini, et al.,” Planck-LFI: instrument design and ground calibration strategy”, *Proceedings of the European Microwave Association*, Vol.1, Sept. 2005
5. B. Aja, J.P. Pascual, L. de la Fuente, M. Detratti, E. Artal, A. Mediavilla, P. de Paco, L. Pradell, “Planck-LFI 44-GHz Back End Module”, *IEEE Transactions on Aerospace and Electronic Systems*, Vol.41, Issue 4, pp. 1415-1430, Oct. 2005
6. J.P. Pascual, B. Aja, M.L de la Fuente, T. Pomposo, E. Artal., “ System Simulation of a differential Radiometer Using Standard RF-Microwave Simulators”, *Simulation, Transactions of the Society for Modeling and Simulation International*, Vol. 81, Issue 11, pp.735-755, Nov. 2005
7. A. Mennella, B. Aja, E. Artal, M. Balasini, G. Baldan et al., “Calibration and testing of the Planck-LFI QM instrument”, *Proc. of SPIE*, Vol. 6265, pp. 62650G-1- 62650G-12, July 2006

Congresos Internacionales

1. E. Artal, B. Aja, M. L. De la Fuente, C. Palacios, A. Mediavilla, J. P. Pascual, J. Portilla, “Low 1/f Noise 30 GHz Broadband Amplifiers for the Differential Radiometers of the Planck Surveyor Mission”, *Conference Proceedings 31st European Microwave Conference*, Vol. 2, pp. 61-64. London, UK, Sept. 2001
2. B. Aja, M.L. De la Fuente, J.P. Pascual, A. Mediavilla, E. Artal, “Low Noise Monolithic Ka-Band P-HEMT Amplifier for Space Applications”, *Conference Proceedings of the European Gallium Arsenide and other semiconductors Applications Symposium (GAAS 2001)*, pp. 85-88, London, UK, Sept. 2001
3. M. Detratti, B. Aja, J. P. Pascual, M. L. De la Fuente , E. Artal, “Millimeter Wave Microstrip Broadband Bandpass Filters Design and Test”, *Conference Proceedings 32nd European Microwave Conference*, Vol. 2, pp. 573-575, Milano (Italy), Sept. 2002
4. B. Aja, M.L. De la Fuente, J.P. Pascual, A. Mediavilla, M. Cryan, E. Artal, “Q-Band Monolithic GaAs PHEMT Low Noise Amplifiers: Comparative Study of Depletion and Enhancement Mode Transistors”,

Conference Proceedings the European Gallium Arsenide and other semiconductors Applications Symposium, pp. 53-56. Milano (Italy), Sept. 2002

5. E. Artal, B. Aja, M.L. De la Fuente, N. Roddis, D. Kettle, F. Winder, L. Pradell, P. de Paco, “Radiometers at 30 and 44 GHz for the Planck mission”, *Conference Proceedings Microwave Technology and Techniques Workshop*, pp. 41-48, ESTEC (Netherlands), 8-9 Oct. 2002
6. A. Mennella, M. Bersanelli, R.C. Butler, D. Maino, N. Mandolesi, G. Morgante, L. Valenziano, F. Villa, T. Gaier, M. Seiffert, S. Levin, N. Roddis, D. Kettle, F.Winder, B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, A. Mediavilla, L. Pradell, P. de Paco, et. al., “Advanced pseudo-correlation radiometers for the Planck-LFI instrument”, *Proceedings of the 3rd ESA Workshop on Millimeter Wave Technology and Techniques and Applications*, pp. 69-74, Millilab, Espoo (Finland), 21-23 May 2003
7. N. Roddis, D. Kettle, F.Winder, B. Aja, E. Artal, M.L. De la Fuente, J.P. Pascual, A. Mediavilla, L. Pradell, P. de Paco, “Differential Radiometer at 30 GHz for the Planck mission”, *Proceedings of the 3rd ESA Workshop on Millimeter Wave Technology and Techniques and Applications*, pp. 81-86, Millilab, Espoo, Finland, 21-23 May 2003
8. B. Aja, J.P. Pascual, M.L. De la Fuente, J. Gallegos, E. Artal, “A New Method to Obtain Total Power Receiver Equivalent Noise Temperature”, *Proceedings 33rd European Microwave Conference*, pp. 355-358., ICM, Munich (Germany), Oct. 2003
9. J.P. Pascual, B. Aja, M.L. De la Fuente, E. Artal, “Radiometer Simulation using RF Platforms”, *Proceedings 2004 International Workshop on Electronics and System Analysis*, pp. 119-122, U.P.V/E.H.U. Fac. de Ciencia y Tecnología, Bilbao (España), Oct. 2004
10. B. Aja, E. Artal, M.L. De la Fuente, J.P. Pascual, A. Mediavilla, N. Roddis, D. Kettle, F.Winder, L. Pradell, P. de Paco, “Very Low Noise Differential Radiometer at 30 GHz”, *Proceedings 34th European Microwave Conference*, pp. 749-752, RAI, Amsterdam, Netherlands, Oct. 2004
11. Danielle Kettle, Beatriz Aja, “Radiometer at 30 GHz for the Planck Mission”, *Proceedings of the 13th International Conference of Women Engineers and Scientists*, pp. 142, Seoul, South Korea, 28 Aug. 2005
12. E. Artal, B. Aja, M.L. De la Fuente, J.P. Pascual, A. Mediavilla, “Back End Module Parameters for 44 GHz Broadband Millimetre Wave Differential Radiometer”, *Proceedings 35th European Microwave Conference*, pp. 1219-1222, Paris, France, Oct. 2005
13. E. Barajas, B. Aja, M.L. De la Fuente, J.P. Pascual, E. Artal, “Low Noise High Linearity Ultra Broadband Monolithic Amplifier Using Travelling-Wave Gain Stages”, *Proceedings of the 35th European Microwave Conference*, pp. 1091-1094, Paris, France, Oct. 2005
14. E. Artal, B. Aja, R. Garcia, M. Detratti, L.A. Rodriguez, “Measurement of Active and Passive Millimetre Wave Devices Using Coplanar to Microstrip Transitions”, *Proceedings 4th ESA Workshop on Millimetre Wave Technology and Applications Conference*, pp. 153-158, Espoo, Finland, 15-17 Feb. 2006
15. B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, J. L. Cano “Three Port Stability Analysis of Broadband Millimetre Wave MMIC Amplifier”, *Proceeding of the 1st European Microwave Integrated Circuits Conference, EuMIC*, Manchester, UK, pp. 399-402, Sept. 2006
16. B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, “Effective Bandwidth Improvement Technique Based On Mismatch Analysis”, *Proceedings 36th European Microwave Conference, EuMC,* Manchester, UK, pp. 1501-1504, Sept. 2006
17. E. Artal, M.L. de la Fuente, B. Aja, “Millimetre wave MMIC Amplifiers for Broadband Direct Detection Radiometers”, *Workshop: New Horizons for Radio Astronomy Techniques, EuRad,* Manchester, UK, Sept. 2006

Congresos Nacionales

1. Aja Abelán B., De la Fuente Rodríguez M.L., Pascual Gutiérrez J.P., Mediavilla Sánchez A., Artal Latorre E., “Amplificadores MMIC en la Banda Ka de Banda Ancha”, *URSI XVI Simp. Nacional, Actas del Simposium, pp. 427-428*, Madrid, Septiembre 2001
2. Artal Latorre E., Aja Abelán B., De la Fuente Rodríguez M.L., Palacios C., Mediavilla Sánchez A., Pascual Gutiérrez J.P., Portilla Rubín, J., “Demostrador del Módulo Posterior del Radiómetro de 30 GHz de Planck”, *URSI XVI Simp. Nacional, Actas del Simposium*, pp. 15-16, Madrid, Septiembre 2001

3. Palacios C., Artal Latorre E., Aja Abelán B., “Ancho de Banda Efectivo en Radiómetros de Bandas Milimétricas”, *URSI XVI Simp. Nacional, Actas del Simposium*, pp. 279-280, Madrid, Septiembre 2001
4. de la Fuente Rodríguez M.L., Aja Abelán B., Valiente F., Pascual Gutiérrez, J.P., Artal Latorre E., “Sistema de Medida de Ruido en Bandas Milimétricas”, *URSI XVI Simp. Nacional, Actas del Simposium*, pp. 345-346, Madrid, Septiembre 2001.
5. Aja B., De la Fuente L., Pascual J.P., Cryan M., Artal E., “Amplificadores MMIC en la Banda Q utilizando transistores de enriquecimiento y de deplexión”, *URSI XVII Simp. Nacional, Actas del Simposium*, pp. 63-64, Alcalá de Henares (Madrid), Septiembre 2002
6. Artal Latorre, Eduardo; Aja Abelán, Beatriz; Dettrati, Marco; De la Fuente Mª Luisa; Mediavilla Sánchez, Ángel; Pascual Juan Pablo. “Radiómetros del instrumento LFI de la misión Planck”, *URSI XVII Simp. Nacional, Actas del Simposium*, pp. 271-272, Alcalá de Henares (Madrid), Septiembre 2002
7. Aja B., Artal E., de la Fuente L., Pascual J.P. , Mediavilla A., Bara M., Blanco E., Pradell L., de Paco P., “Modulo Posterior del Radiómetro Planck a 30 GHz: Modelo de Calificación”, *URSI 2004 XIX Simp. Nacional, Actas del Simposium*, pp. 93, Universitat Ramon Llull (Barcelona), Septiembre 2004
8. Aja B., de la Fuente L., Pascual J.P., Artal E., “Técnica de Mejora del Ancho de Banda Efectivo en el Módulo Posterior del Radiómetro Planck”, *URSI 2004 XIX Simp. Nacional, Actas del Simposium*, pp. 93, Universitat Ramon Llull (Barcelona), Septiembre 2004
9. Aja B., de la Fuente L., Pascual J.P., Artal E., “Simulación del Radiómetro a 30 GHz de la Misión Planck”, *URSI 2004 XIX Simp. Nacional, Actas del Simposium*, pp. 161, Universitat Ramon Llull (Barcelona), Septiembre 2004
10. Eduardo Artal, Beatriz Aja, Mª Luisa de la Fuente, Juan P. Pascual, Ángel Mediavilla, “Demostradores de los módulos posteriores de 44 GHz para la misión Planck”, *URSI 2005 XI Simp. Nacional, Actas del Simposium*, pp. 174, Universidad Politécnica de Valencia – Gandia (Valencia), Septiembre 2005

Anexo A

Esquemas de una Rama de los Módulos Posteriores del Radiómetro Planck

A.1. Introducción

A continuación se muestran los esquemas para cada una de las ramas de los módulos posteriores (BEM) a 30 y 44 GHz. Se indican los componentes utilizados en los diseños. Algunos de estos componentes cambian en las unidades de los BEM de calificación o de vuelo.

A.2. Rama del Módulo Posterior de 30 GHz

El esquema de una rama del BEM a 30 GHz se muestra en la Figura A.1. En cada rama, el LNA consta de dos amplificadores de bajo ruido en cascada, con el fin de obtener la ganancia necesaria. A continuación se encuentra el filtro microstrip paso banda, el detector cuadrático y por último el amplificador de continua.

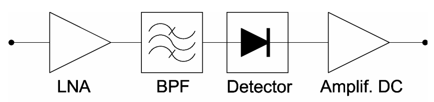

Figura A.1. Esquema de una rama del módulo posterior a 30 GHz

La Figura A.2 muestra con más detalle cada uno de los subsistemas que forman una rama, con la entrada de RF y la transición como primer elemento, las alimentaciones de +5 V y -5 V y la salida equilibrada del amplificador de continua.

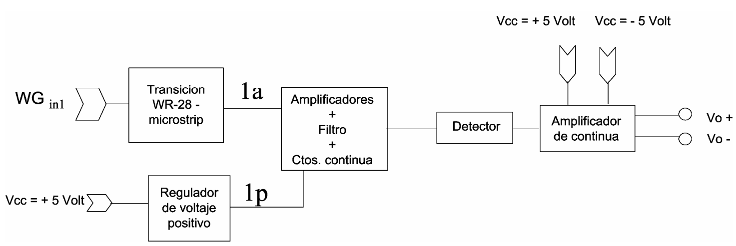

Figura A.2. Esquema de una rama en el BEM de 30 GHz

En los siguientes apartados se detalla el esquema eléctrico y los componentes de los elementos que forman el sistema de la Figura A.2.

A.2.1. Regulador positivo

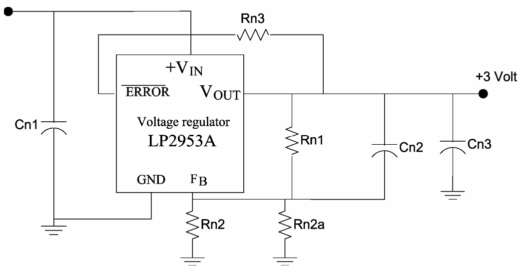

Figura A.3. Regulador de voltaje positivo del BEM de 30 GHz

Tabla A.1. Componentes del regulador positivo del BEM de 30 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
VR1	Regulador	---	LP2953A	National Semiconductor
Rn1	Resistencia	18.7 kΩ	M55342K02B18E7R	Vishay Sfernice
Rn2	Resistencia	23.7 kΩ	M55342K02B23E7R	Vishay Sfernice
Rn2a	Resistencia	28.7 kΩ	M55342K02B28E7R	Vishay Sfernice
Rn3	Resistencia	100 kΩ	M55342K02B100ER	Vishay Sfernice
Cn1	Capacidad	1 µF	CWR09NB105KBBB	AVX
Cn2	Capacidad	0.1 µF	CWR09NB104KBBB	AVX
Cn3	Capacidad	6.8 µF	CWR09MB685KBBB	AVX

A.2.2. RF y circuitos de protección

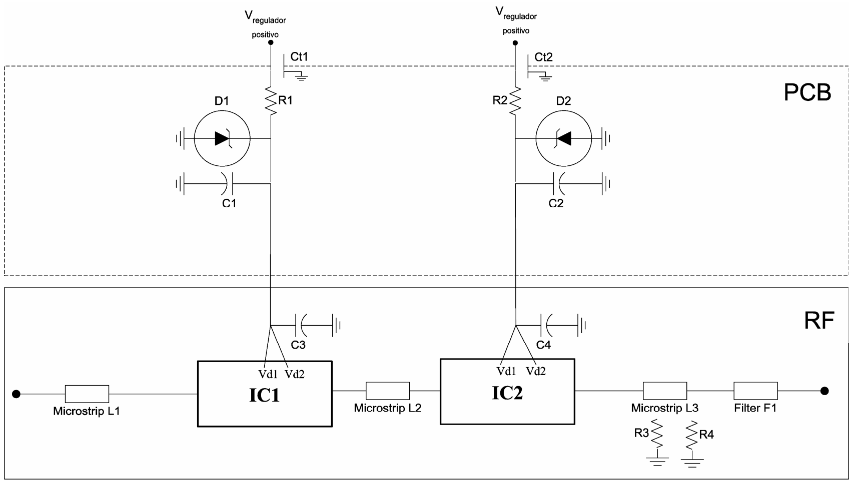

Figura A.4. RF con Amplificadores + Filtro + circuitos de polarización y de protección de continua del BEM de 30 GHz

En la caja de este montaje van dos condensadores pasamuros (Ct1, Ct2), como se muestra en la Figura 6.34.

Los hilos de oro utilizados para las conexiones de los circuitos integrados, líneas y condensadores en la parte de RF son de diámetro 17.5 µm, y en estas conexiones se utiliza un sólo hilo de oro. Para la ecualización se utilizan dos hilos de oro que unen las resistencias R3 y R4 a la línea microstrip L3. Para unir el filtro de Duroid, se pega cinta de oro (de grosor 25 µm y anchura 0.254 mm) con epoxy sobre el filtro y se une mediante varios hilos de oro soldado a la línea L3 de 50 Ohm en alúmina. Una fotografía de este montaje se muestra en la Figura 6.32.

La transición de guía de onda a microstrip en la entrada se une a la línea, L1, de 50 Ohm en Alúmina con un trozo de cinta de oro (de grosor 25 μm y anchura 0.254 mm), que se pega en ambos lados con epoxy. La pasta conductora de epoxy utilizada en todos los casos es la E3081 de Epotek.

Tabla A. 2. Componentes la red de protección del BEM de 30 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
R1	Resistencia	10 Ω	M55342K02B10D0R	Vishay Sfernice
R2	Resistencia	10 Ω	M55342K02B10D0R	Vishay Sfernice
D1	Zener	Vz=4.3 V	1N4623UR-1	CDI
D2	Zener	Vz=4.3 V	1N4623UR-1	CDI
C1	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
C2	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Ct1	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct2	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad

Tabla A.3. Componentes la parte de RF del BEM de 30 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
C3	Capacidad	100 pF	DICAP D20BU101M5PB	DILABS/USA
C4	Capacidad	100 pF	DICAP D20BU101M5PB	DILABS/USA
IC1	MMIC-LNA	---	HMC263	Hittite
IC2	MMIC-LNA	---	HMC263	Hittite
R3	Resistencia	1 kΩ	S0302AP102JG	SOTA
R4	Resistencia	1 kΩ	S0302AP102JG	SOTA
L1	Línea microstrip	50 Ω@ 30GHz	Alumina	Reinhardt Microtech
L2	Línea microstrip	50 Ω@ 30GHz	Alúmina	Reinhardt Microtech
L3	Línea microstrip	50 Ω@ 30GHz	Alúmina	Reinhardt Microtech
F1	Filtro paso banda	μstrip Coupled lines	F30_D2_20 (Duroid 6002)	Rogers Corporation

A.2.3. Detector

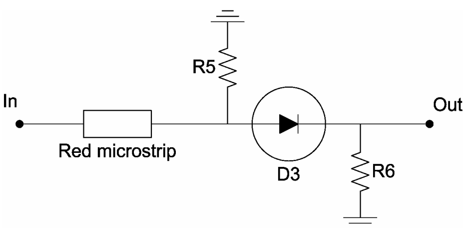

Figura A.5. Detector del BEM de 30 GHz

Tabla A.4. Componentes del detector del BEM de 30 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
D3	Diodo GaAs	---	HSCH 9161	Agilent Technologies
R5	Resistencia	100 Ω	S0302EP101JG	SOTA
R6	Resistencia	100 kΩ	M55342K02B100ER	Vishay Sfernice

A.2.4. Amplificador de continua

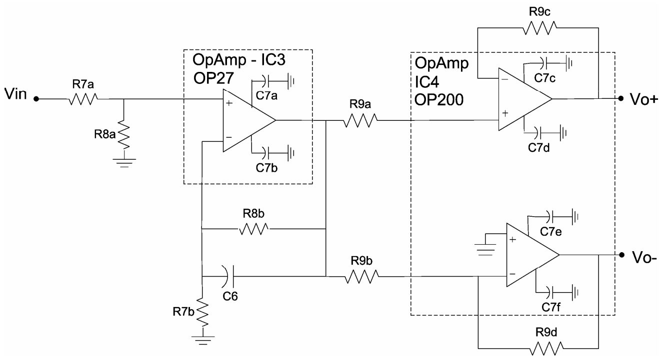

Figura A.6. Amplificador de continua

Tabla A.5. Componentes del amplificador de continua del BEM de 30 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
IC3	Amplificador operacional	---	OP27AJ	Burr-Brown
IC4 (a,b)	Amplificador operacional	---	OP200A	Analog Devices
R7 a (R1)	Resistencia	51 kΩ	M55342K02B51ER	Vishay Sfernice
R7 b (R3)	Resistencia	100 Ω	M55342K02B100DR	Vishay Sfernice
R8 a (R2)	Resistencia	51 kΩ	M55342K02B51ER	Vishay Sfernice
R8 b (R4)	Resistencia	39 kΩ	M55342K02B39ER	Vishay Sfernice
R9 (a,b,c,d) (R5)	Resistencia	10 kΩ	M55342K02B10ER	Vishay Sfernice
C6	Capacidad	47 pF	CDR01BP470BJNM	AVX
C7 (a,b,c,d,e,f)	Capacidad	33 nF	CDR32BX333AJNM	AVX

A.3. Módulo Posterior de 44 GHz

El esquema de una rama del BEM a 44 GHz se muestra en la Figura A.7. En cada rama, el LNA consta de dos amplificadores de bajo ruido y atenuadores microstrip en cascada. A continuación se encuentra el filtro microstrip paso banda, el detector cuadrático y por último el amplificador de continua.

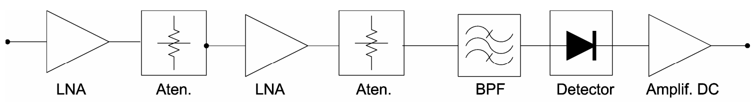

Figura A.7. Esquema de una rama del módulo posterior a 44 GHz

La Figura A.8 muestra con más detalle cada uno de los subsistemas que forman una rama, con la entrada de RF y la transición como primer elemento, las alimentaciones de +5 V y -5 V y la salida equilibrada del amplificador de continua.

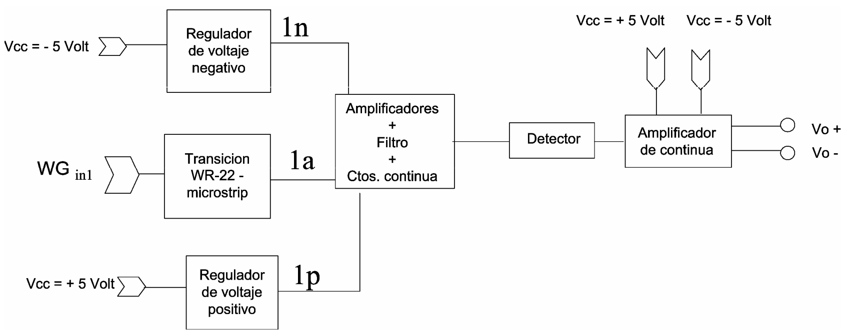

Figura A.8. Esquema de una rama en el BEM de 44 GHz

En los siguientes apartados se detalla el esquema eléctrico y los componentes de los elementos que forman el sistema de la Figura A.8.

A.3.1. Regulador positivo

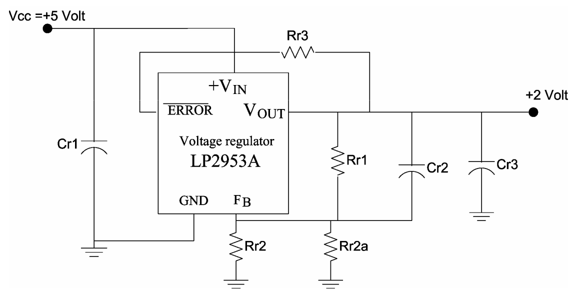

Figura A.9. Regulador de voltaje positivo del BEM de 44 GHz

Tabla A.6. Componentes del regulador positivo del BEM de 44 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
VR1	Regulador	---	LP2953A	National Semiconductors
Rr1	Resistencia	7k5 Ω	M55342K02B7E5R	Vishay Sfernice
Rr2	Resistencia	23.7 kΩ	M55342K02B23E7R	Vishay Sfernice
Rr2a	Resistencia	23.7 kΩ	M55342K02B23E7R	Vishay Sfernice
Rr3	Resistencia	100 kΩ	M55342K02B100ER	Vishay Sfernice
Cr1	Capacidad	1 µF	CWR09NB105KBBB	AVX
Cr2	Capacidad	0.1 µF	CWR09NB104KBBB	AVX
Cr3	Capacidad	6.8 µF	CWR09MB685KBBB	AVX

A.3.2. Regulador negativo

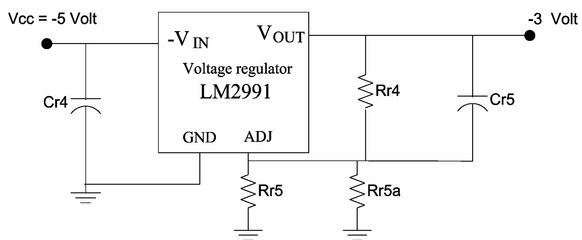

Figura A.10. Regulador de voltaje negativo del BEM de 44 GHz

Tabla A.7. Componentes del regulador negativo del BEM de 44 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
VR2	Regulador	---	LM2991	National Semiconductors
Rr4	Resistencia	3320 Ω	M55342K02B3E32R	Vishay Sfernice
Rr5	Resistencia	4400 Ω	M55342K02B4E4R	Vishay Sfernice
Rr5a	Resistencia	4400 Ω	M55342K02B4E4R	Vishay Sfernice
Cr4	Capacidad	1 μF	CWR09NB105KBBB	AVX
Cr5	Capacidad	1 μF	CWR09NB105KBBB	AVX

A.3.3. Parte de RF y circuitos de polarización y protección

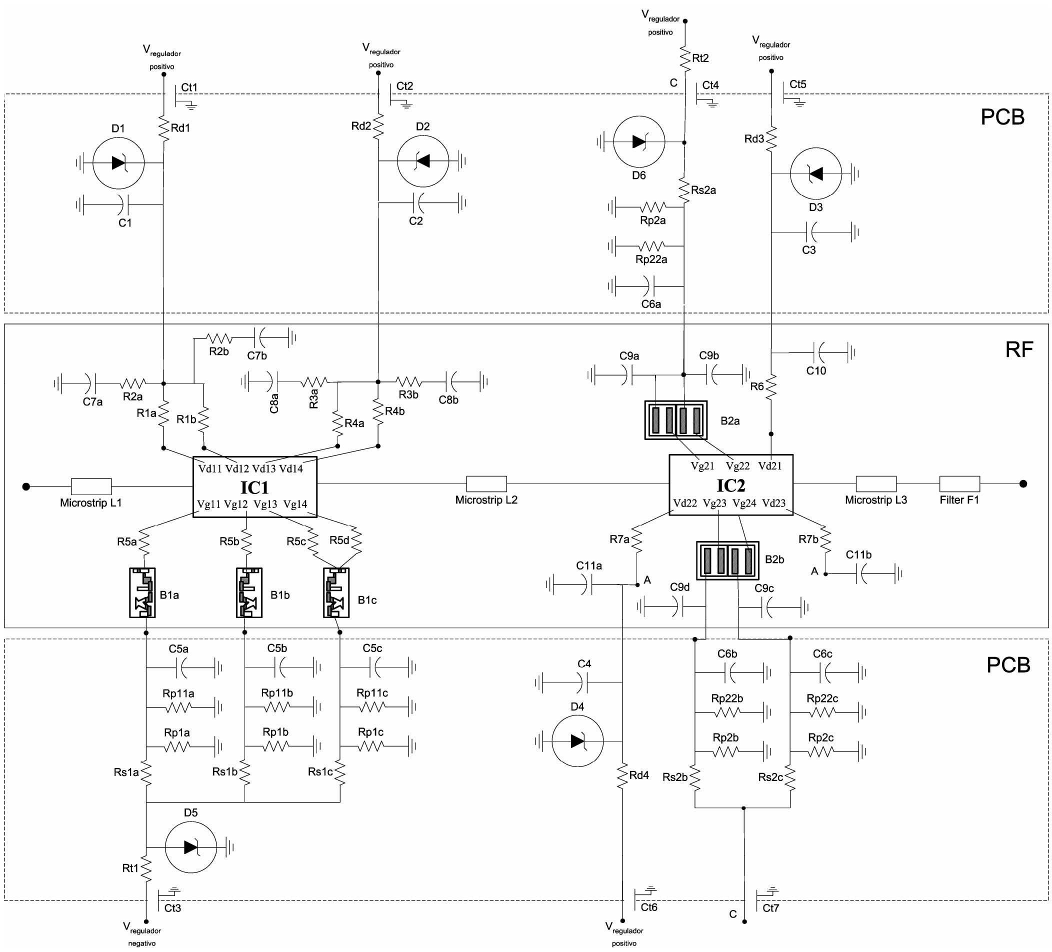

Figura A.11. Amplificadores de RF, filtro y circuitos de polarización y de protección de continua del BEM de 44 GHz

En la caja de este montaje van siete pasamuros como se muestra en la Figura 6.76. Tres pasamuros son para la polarización del primer MMIC (IC1), dos de los drenadores y uno de todas las puertas. Los otros cuatro pasamuros son para la polarización del segundo MMIC (IC2), dos de las puertas y dos de los drenadores.

Al igual que en los prototipos de 30 GHz, los hilos de oro utilizados para las conexiones de los circuitos integrados, líneas y condensadores en la parte de RF son de diámetro 17.5 μm, y en estas conexiones se utiliza un sólo hilo de oro. Para unir el filtro de Duroid F1, se pega cinta de oro (de grosor 25 μm y anchura 0.254 mm) con epoxy sobre el filtro y se une mediante varios hilos de oro soldado a la línea L3 de 50 Ohm en alúmina. Una fotografía de este montaje se muestra en la Figura 6.75.

La transición de guía de onda a microstrip en la entrada se une a la línea de 50 Ohm en alúmina con un trozo de cinta de oro (de grosor 25 m y de anchura 0.254 mm), y se pega en ambos lados con epoxy. La pasta conductora de epoxy utilizada en todos los casos es la E3081 de Epotek.

Tabla A.8. Componentes de polarización y protección del BEM de 44 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
Rd1	Resistencia	10 Ω	M55342K02B10D0R	Vishay Sfernice
D1	Zener	Vz = 2.2 V	1N4616UR-1	CDI
C1	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Rd2	Resistencia	75 Ω	M55342K02B75DR	Vishay Sfernice
D2	Zener	Vz = 2.2 V	1N4616UR-1	CDI
C2	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Rd3	Resistencia	10 Ω	M55342K02B10DR	Vishay Sfernice
D3	Zener	Vz = 2.2 V	1N4616UR-1	CDI
C3	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Rd4	Resistencia	10 Ω	M55342K02B10DR	Vishay Sfernice
D4	Zener	Vz = 2.2 V	1N4616UR-1	CDI
C4	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Rt1	Resistencia	61.9 kΩ	M55342K02B61E9R	Vishay Sfernice
D5	Zener	Vz = 2.2 V	1N4616UR-1	CDI
Rs1 (a,b,c)	Resistencia	23.7 kΩ	M55342K02B23E7R	Vishay Sfernice
Rp1 (a,b,c)	Resistencia	11.5 kΩ	M55342K02B11E5R	Vishay Sfernice
Rp11 (a,b,c)	Resistencia	100 kΩ	M55342K02B100ER	Vishay Sfernice
C5 (a,b,c)	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Rt2	Resistencia	23.7 kΩ	M55342K02B23E7R	Vishay Sfernice
D6	Zener	Vz = 2.2 V	1N4616UR-1	CDI
Rs2 (a,b,c)	Resistencia	21.5 kΩ	M55342K02B21E5R	Vishay Sfernice
Rp2 (a,b,c)	Resistencia	53.6 kΩ	M55342K02B53E6R	Vishay Sfernice
Rp22 (a,b,c)	Resistencia	100 kΩ	M55342K02B100ER	Vishay Sfernice
C6 (a,b,c)	Capacidad	0.1 μF	CWR09NB104KBBB	AVX
Ct1	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct2	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct3	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct4	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct5	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct6	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad
Ct7	Capacidad	33 nF	FC030-3-333-SV-25HT	Eurofarad

Tabla A.9. Componentes de la parte de RF y de polarización del BEM de 44 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
L1	Línea microstrip	50 Ω@ 44GHz		Reinhardt Microtech
L2	Atenuador microstrip	3/5 dB	BE44-1212/BE44-1222	Thin Film Products
L3	Atenuador microstrip	3/13 dB	BE44-1213/BE44-1223	Thin Film Products
F1	Filtro paso banda	μstrip Coupled lines	F44_3E_A20_2 (Duroid 6002)	Rogers Corporation
IC1	MMIC-LNA	---	mc_lna44 (P20H20_2C4)	OMMIC
IC2	MMIC-LNA	---	Lf_lna443v (P20H1_2H1)	OMMIC
R2 (a,b)	Resistencia	100 Ω	S0302 P101JG	SOTA/USA
C7 (a,b)	Capacidad	22 pF	DICAP D15BH220M5PB	DILABS/USA
R1 (a,b)	Resistencia	10 Ω	S0302 AP100JG	SOTA/USA
R3 (a,b)	Resistencia	100 Ω	S0302 P101JG	SOTA/USA
C8 (a,b)	Capacidad	22 pF	DICAP D15BH220M5PB	DILABS/USA
R4 (a,b)	Resistencia	10 Ω	S0302 AP100JG	SOTA/USA
B1 (a,b,c)	Bias Filter Network	---	B28BHBFN01	DILABS/USA
R5 (a,b,c,d)	Resistencia	100 Ω	S0302 AP101JG	SOTA/USA

C9 (a,b,c,d)	Condensador	100 pF	DICAP D20BU101M5PB	DILABS/USA
B2 (a,b)	RF Blocking Network	---	J30BHBA02LX2	DILABS/USA
C10	Condensador	100 pF	DICAP D20BU101M5PB	DILABS/USA
R6	Resistencia	10 Ω	S0302 AP100JG	SOTA/USA
C11 (a,b)	Condensador	100 pF	DICAP D20BU101M5PB	DILABS/USA
R7 (a,b)	Resistencia	10 Ω	S0302 AP100JG	SOTA/USA

A.3.4. Detector

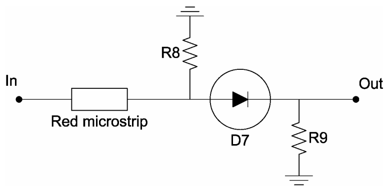

Figura A.12. Detector del BEM de 44 GHz

Tabla A.10. Componentes del detector del BEM de 44 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
D7	Diodo GaAs	---	HSCH 9161	Agilent Technologies
R8	Resistencia	100 Ω	S0302EP101JG	SOTA
R9	Resistencia	100 kΩ	M55342K02B100ER	Vishay Sfernice

A.3.5. Amplificador de continua

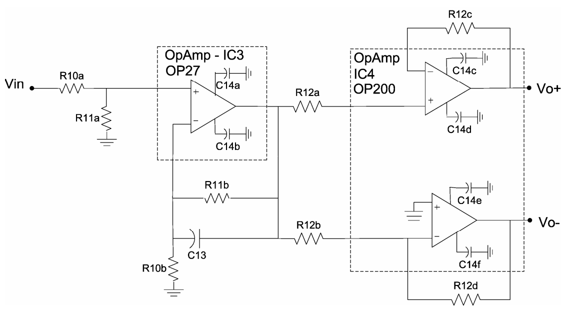

Figura A.13. Amplificador de continua del BEM de 44 GHz

Tabla A.11. Componentes del amplificador de continua del BEM de 44 GHz

Referencia	Descripción	Valor	Referencia	Fabricante
IC3	Amplificador operacional	---	OP27AJ	Burr-Brown
IC4 (a,b)	Amplificador operacional	---	OP200A	Analog Devices
R10a (R1)	Resistencia	100 Ω	M55342K02B100DR	Vishay Sfernice
R10b (R3)	Resistencia	100 Ω	M55342K02B100DR	Vishay Sfernice
R11a (R2)	Resistencia	51 kΩ	M55342K02B51ER	Vishay Sfernice
R11b (R4)	Resistencia	3.6 kΩ	M55342K02B3E6R	Vishay Sfernice
R12 (a,b,c,d) (R5)	Resistencia	10 kΩ	M55342K02B10ER	Vishay Sfernice
C13 (C1)	Capacidad	47 pF	CDR01BP470BJNM	AVX
C14 (a,b,c,d,e,f) (C)	Capacidad	33 nF	CDR32BX333AJNM	AVX

A.3.6. Atenuadores microstrip

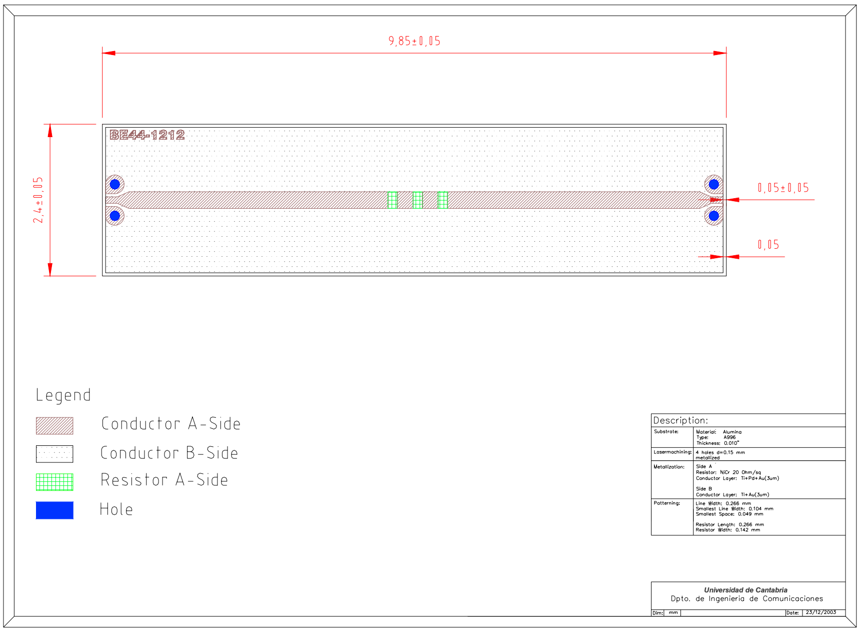

Figura A.14. Atenuador 3 dB en Alumina (l = 9.9 mm) con transiciones coplanar microstrip

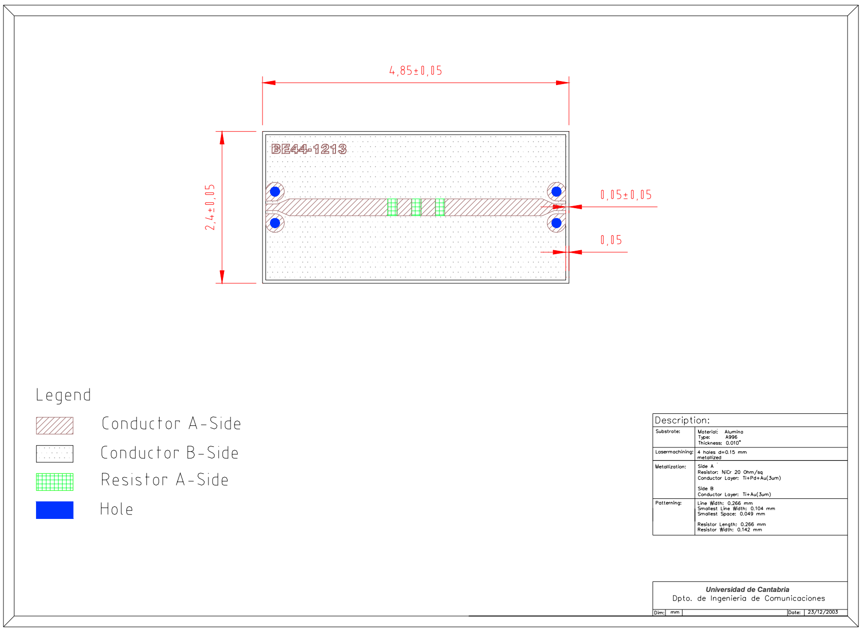

Figura A.15. Atenuador 3 dB en Alumina (l = 4.9 mm) con transiciones coplanar microstrip

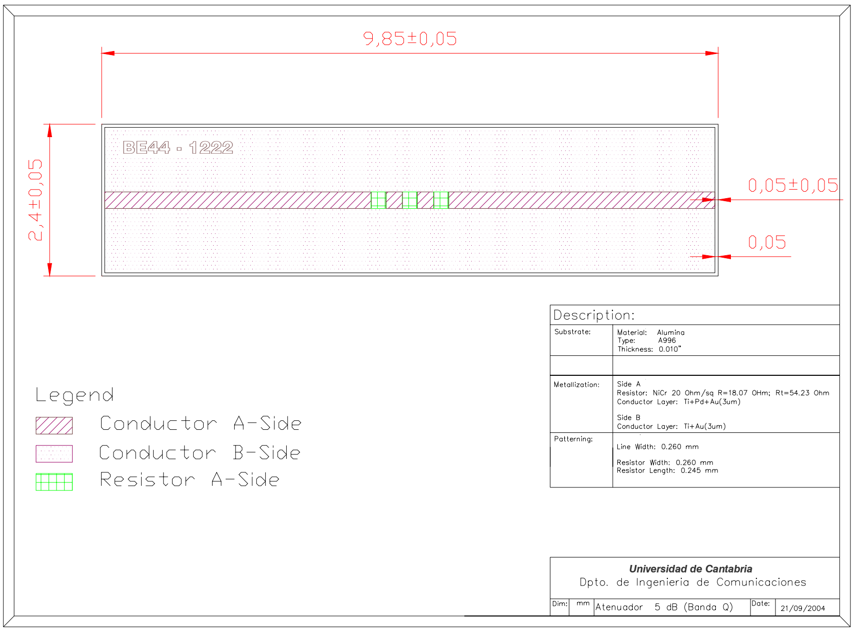

Figura A.16. Atenuador 5 dB en Alumina (l = 9.9 mm) con transiciones coplanar microstrip

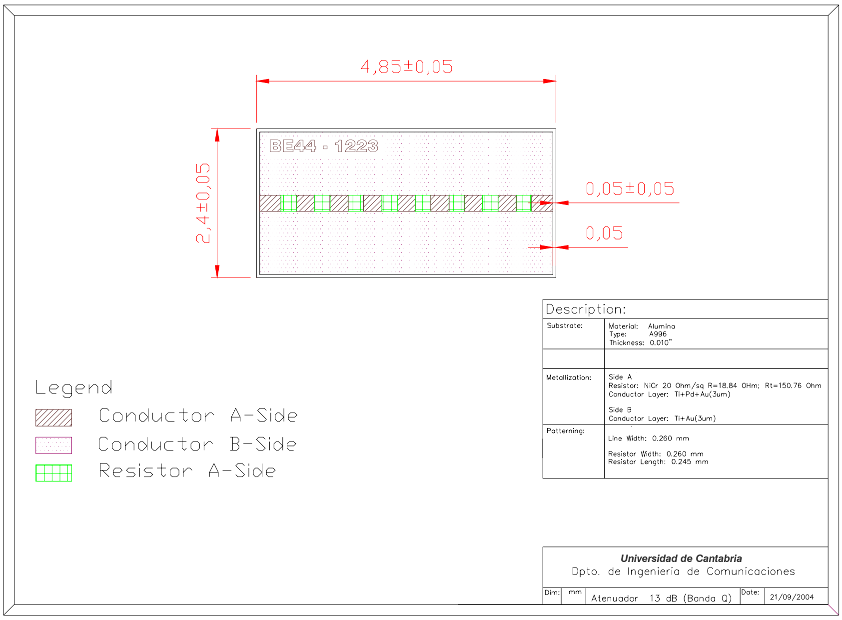

Figura A.17. Atenuador 13 dB en Alumina (l = 4.9 mm) con transiciones coplanar microstrip

Referencias

[1] ESA Science & Technology: Planck Science Team Home: http://www.rssd.esa.int/index.php?project=PLANCK

[2] European Space Agency, "PLANCK, The Scientific Programme", ESA-SCI (2005)1

[3] J. A. Tauber, "The Planck Mission: Overview and Capabilities for Observing Extended Emission", *ISO Beyond Point Sources: Studies of Extended Infrared Emission*, Madrid, Spain, 14-17 Sept. 1999

[4] J. A. Tauber, "The Planck Mission", *The Extragalactic Infrared Background and its Cosmological Implications, Proceedings of IAU Symposium*, Vol. 204, Manchester, UK, Aug. 2001

[5] N. Mandolesi, M. Bersanelli, C. Burigana, F. Villa, "The Planck Low Frequency Instrument", *Astrophys. Lett & Comm, in press. Proceedings. of the Conference: "The Cosmic Microwave Background and the Planck Mission"*, Santander, Spain, 22-25 Jun. 1998

[6] Mennella, A.; Bersanelli, M.; Butler, R. C.; Maino, D.; Mandolesi, N.; Morgante, G.; Valenziano, L.; Villa, F.; Gaier, T.; Seiffert, M.; Levin, S.; Lawrence, C.; Meinhold, P.; Lubin, P.; Tuovinen, J.; Varis, J.; Karttaavi, T.; Hughes, N.; Jukkala, P.; Sjman, P.; Kangaslahti, P.; Roddis, N.; Kettle, D.; Winder, F.; Blackhurst, E.; Davis, R.; Wilkinson, A.; Castelli, C.; Aja, B.; Artal, E.; de La Fuente, L.; Mediavilla, A.; Pascual, J. P.; Gallegos, J.; Martinez-Gonzalez, E.; de Paco, P.; Pradell, L., "Advanced Pseudo-correlation Radiometers for the Planck-LFI Instrument", *Proceedings of the 3rd ESA Workshop on Millimeter Wave Technology and Techniques and Applications*, pp. 69-74., Millilab, Espoo, Finland, 21-23 May 2003

[7] M. Bersanelli, B. Aja, E. Artal, M. Balasini, et al.,"Planck-LFI: Instrument Design and Ground Calibration Strategy", *Proceedings of the European Microwave Association*, Vol. 1, Sept. 2005

[8] E. Artal, B. Aja, M. L. de la Fuente, C. Palacios, A. Mediavilla, J. P. Pascual, J. Portilla, "Low 1/f Noise 30 GHz Broadband Amplifiers for the Differential Radiometers of the Planck Surveyor Mission", *Proceedings of the 31st European Microwave Conference*, Vol. 2, pp. 61-64. London, UK, Sept. 2001

[9] B. Aja, J.P. Pascual, L. de la Fuente, M. Detratti, E. Artal, A. Mediavilla, P. de Paco, L. Pradell, "Planck-LFI 44-GHz Back End Module", *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 41, Issue 4, pp. 1415-1430, Oct. 2005

[10] E. Artal, B. Aja, M.L. de la Fuente, J.P. Pascual, A. Mediavilla, "Back End Module Parameters for 44 GHz Broadband Millimetre Wave Differential Radiometer", *Proceedings of the 35th European Microwave Conference*, pp. 1219-1222, Paris, France, Oct. 2005

[11] E. Artal, B. Aja, M.L. de la Fuente, N. Roddis, D. Kettle, F.Winder, L.Pradell, P. de Paco, "Radiometers at 30 and 44 GHz for the Planck Mission", *Conference Proceedings of Microwave Technology and Techniques Workshop*, pp. 41-48., ESTEC - Netherlands, 8-9 Oct. 2002

[12] N. Roddis, D. Kettle, F.Winder, B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, A. Mediavilla, L. Pradell, P. de Paco, "Differential Radiometer at 30 GHz for the Planck Mission", *Proceedings of the 3rd ESA Workshop on Millimeter Wave Technology and Techniques and Applications*, pp. 81-86., Millilab, Espoo, Finland, 21-23 May 2003

[13] B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, A. Mediavilla, N. Roddis, D. Kettle, F. Winder, L. Pradell, P. de Paco, "Very Low Noise Differential Radiometer at 30 GHz", *Proceedings of the 34th European Microwave Conference*, pp. 749-752., RAI, Amsterdam, Netherlands, Oct. 2004

[14] Beatriz Aja, Eduardo Artal, Luisa de la Fuente, Juan Pablo Pascual, Angel Mediavilla, Neil Roddis, Danielle Kettle, W. Frank Winder, Lluis Pradell i Cara, and Pedro de Paco, "Very Low-Noise Differential Radiometer at 30 GHz for the PLANCK LFI", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, Issue 6, pp. 2050-2062, Jun. 2005

[15] Danielle Kettle, Beatriz Aja, "Radiometer at 30 GHz for the Planck Mission", *Proceedings of the 13th International Conference of Women Engineers and Scientists*, pp. 142., Seoul, South Korea, 28 Aug. 2005

[16] K. G. Jansky, "Electrical Disturbances Apparently of Extraterrestrial Origin", *Proceedings of IRE*, Vol. 21, pp. 1387, Oct. 1933

[17] John D. Kraus, "Radio Astronomy", Cygnus-Quasar Books, 2nd Edition, 1986

[18] M.E. Tiuri, "Radio Astronomy Receivers", *IEEE Transactions on Antennas and Propagation*, pp. 930-938, Dec. 1964

[19] F. T: Ulaby, R. K. Moore, A. K. Fung, "Microwave Remote sensing – Active and Passive ", Vol. I, Artech House Inc. 1981

[20] Michael S. Hersman, “Sensitivity of the Total Power Radiometer with Periodic Absolute Calibration”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 29, Issue 1, pp. 32-40, Jan. 1981

[21] Norman C. Jarosik, “Measurements of the Low-Frequency-Gain Fluctuations of a 30-GHz High-Electron-Mobility-Transistor Cryogenic Amplifier”, *IEEE Transactions on Microwave Theory and Techniques*, Issue .44, Issue 2, pp. 193-197, Feb. 1996

[22] E. J. Wollack, “High-electron-mobility-transistor Gain Stability and its Design Implications for Wide Band Millimeter Wave Receivers”, *Review of Scientific Instruments*, Vol. 66, Issue 8, pp. 4305-4312, Aug. 1995

[23] R.H. Dicke, “The Measurements of Thermal Radiation at Microwave Frequencies”, *Review of Scientific Instruments*, Vol. 17, pp. 268-275, Jul. 1946

[24] Flemming Thomsen, “On the Resolution of Dicke-Type Radiometers”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 32, Issue 2, pp.145-150, Feb. 1984

[25] Êmile-Jacqucs Blum,”Sensibilité des Radiotélescopes et Rëcepteurs a Corrélation”, *Annales D’Astrophysique*, Vol. 22, Issue 2, pp. 140-162, Mar.-Apr. 1959

[26] Paul E. Green, “The Output Signal-to-Noise Ratio of Correlation Detectors“, *IRE Transactions on Information Theory*, Vol. 3, Issue 1, pp. 10-18, Mar. 1957

[27] K. Fujimoto, ”On the Correlation Radiometer Technique”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 12, Issue 2, pp. 203-212, Mar. 1964

[28] Graham, M.H., “Radiometer Circuits”, Proc. IRE, vol.46, pp. 1966, 1958

[29] George J.M. Aitken, “A New Correlation Radiometer”, *IEEE Transactions on Antennas and Propagation*, Vol.16, Issue 2, pp. 224-228, Mar. 1968

[30] Robert A. Batchelor, John W. Brooks, B.F.C. Cooper, “Eleven-Centimeter Broadband Correlation Radiometer”, *IEEE Transactions on Antennas and Propagation*, Vol. 16, Issue 2, pp. 228-234, Mar. 1968

[31] Johann-Peter Hach, “A Very Sensitive Airborne Microwave Radiometer using two Reference Temperatures”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 16, Issue 9, pp. 629-636, Sept. 1968

[32] C. Read Predmore, Neal R. Erickson, G. Richard Huguenin, Paul F. Goldsmith, “A Continuous Comparison Radiometer at 97 GHz”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 33, Issue1, pp. 44-51, Jan. 1985

[33] M. Bersanelli, N. Mandolesi, S. Weinreb, R. Ambrosini, G.F. Smoot, “The LFI Differential Receiver Concept”, *Internal Report ITESRE* 177/1995 COBRAS memo n.5

[34] F. Villa, N. Mandolesi and R.C. Butler , “The Planck Project”, IV *National Conference on Infrared Astronomy*, p. 223, Dec. 4-7, Perugia (Italy) 2001

[35] M. Bersanelli, N. Mandolesi, J. Marti-Canales, “Multi-band Radiometer for Measuring the Cosmic Microwave Background”, *Proceedings of the 32nd European Microwave Conference*, Milan, Italy, pp. 547-550, Sept. 2002

[36] N.W. Boggess, J.C. Mather, R. Weiss, C.L. Bennet, E.S. Cheng, E. Dwek, S. Gulkis, M.G. Hauser, M.A. Janssen, T. Kelsall, S.S. Meyer, S.H. Moseley, T.L. Murdock, R.A. Shafer, R.F. Silverberg, G.F. Smoot, D.T. Wilkinson, E.L. Wright, “ The COBE Mission: Its Design and Performance Two Years after Launch”, *The Astrophysical Journal*, 397, Oct. 1992

[37] M.W. Pospieszalski, E.J. Wollack, N. Bailey, D. Thacker, J. Webber, L. D. Nguyen, M. Le, M. Lui, “Design and Performance of Wideband, Low-Noise, Millimeter-Wave Amplifiers for Microwave Anisotropy Probe Radiometers”, *IEEE MTT-S International Microwave Symposium Digest*, Vol. 1, pp. 25-28, 2000

[38] N. Jarosik, C.L. Bennett, M. Halpern, G. Hinshaw, A. Kogut, M. Limon, S.S. Meyer, L. Page, M. Pospieszalski, D.N. Spergel, G.S. Tucker, D.T. Wilkinson, E. Wollack, E.L. Wright, Z. Zhang, “Design, Implementation and Testing of the Map Radiometers”, *The Astrophysical Journal Supplement*, 145, 2003

[39] M. Sandri, M. Bersanelli, C. Burigana, R. C. Butler, M. Malaspina, N. Mandolesi, A. Mennella, G. Morgante, L. Terenzi, L. Valenziano, F.Villa, “Planck Low Frequency Instrument: Beam Patterns”, Proceedings of the 2K1BC Experimental Cosmology at Millimetre wavelengths, *AIP Conference Proceedings*. 616, pp. 242-244, 2002

[40] J.M. Lamarre, J.L. Puget, F. Bouchet et al., “The Planck High Frequency Instrument, a 3rd Generation CMB Experiment, and a Full Sky Submillimeter Survey”, *Proceedings of the workshop on "The Cosmic Microwave Background and its Polarization", New Astronomy Reviews*, 2003

[41] Brossard, J.; Yurchenko, V.; Gleeson, E.; Longval, Y.; Maffei, B.; Murphy, A.; Ristorcelli, I.; Lamarre, J.-M., “PLANCK-HFI: Performances of an Optical Concept for the Cosmic Microwave Background Anisotropies Measurement”, *Proceedings of the 5th International Conference on Space Optics (ICSO 2004)*, pp. 333-340, 30 March - 2 April 2004, Toulouse, France

[42] A. Mennella, M. Bersanelli, B. Cappellini, D. Maino, P. Platania, S. Garavaglia, R.C. Butler, N. Mandolesi, F. Pasian, O. D’arcangelo, A. Simoneto, C. Sozzi, “The Low Frequency Instrument in the ESA Planck Mission”, *Proceedings of International Symposium on Plasmas in the Laboratory and in the Universe: New Insights and New Challenges*, Como, Italy, Sept. 2003

[43] N. Mandolesi, C. Burigana, R.C. Butler, F. Cuttaia, A. de Rosa, F. Finelli, E. Franceschi, A. Gruppuso, M. Malaspina, G. Morgante, G. Morigi, L. Popa, M. Sandri, L. Stringhetti, L. Terenzi, L. Valenziano, F. Villa, ”The Planck Low Frequency Instrument”, *Proceedings of JENAM 2004 Meeting "The Many Scales in the Universe"*, Granada, Spain, 13-17 Sept. 2004

[44] S. Okwit, “An Historical View of The Evolution of Low-Noise Concepts and Techniques”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 32, pp.1068-182, Sept. 1984

[45] James J. Whelehan, “Low-Noise Amplifiers – Then and Now”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 50, Issue 3, pp. 806-813, Mar. 2002

[46] J. C. Webber and M. W. Pospieszalski, “Microwave Instrumentation for Radio Astronomy”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 50, Issue 3, pp. 986-995, Mar. 2002

[47] Marian W. Pospiezalski, “Extremely Low-Noise Amplification with Cryogenic FETs and HFETs:1970-2004, *IEEE Microwave Magazine*, pp. 62-75, Sept. 2005

[48] Whelan, C.S., Marsh, P.F., Hoke, W.E., McTaggart, R.A., Lyman, P.S., Lemonias, P.J., Lardizabal, S.M., Leoni, R.E., Lichwala, S.J., Kazior, T.E., “Millimeter-wave Low-Noise and High-Power Metamorphic HEMT Amplifiers and Devices on GaAs Substrates”, *IEEE Journal of Solid-State Circuits*, Vol. 35, Issue 9, pp. 1307-1311, Sept. 2000

[49] A. Tessmann , M. Kuri, M. Riessle, H. Massler, M. Zink, W. Reinert, W. Bronner, A. Leuther, “A Compact W-Band Dual Receiver Module”, *IEEE MTT-S International Microwave Symposium Digest*, pp. 85-88, Jun. 2006

[50] Bautista, J.J., Bowen, J.G., Fernandez, N.E., Fujiwara, Z., Loreman, J., Petty, S., Prater, J.L., Grunbacher, R., Lai, R., Nishimoto, M., Murti, M.R., Laskar, J., “Cryogenic, X-band and Ka-band InP HEMT based LNAs for the Deep Space Network”, *IEEE Proceedings Aerospace Conference*, Vol. 2, pp. 829-842, Mar. 2001

[51] Christophe Risacher, Victor Belitsky, “GaAs HEMT Low-Noise Cryogenic Amplifiers from C-Band to X-Band with 0.7K/GHz Noise Temperature”, *IEEE Microwave and Wireless Components Letters*, Vol. 13, Issue 3, pp. 96-98, Mar. 2003

[52] Wadefalk, N., Mellberg, A., Angelov, I., Barsky, M.E., Bui, S., Choumas, E., Grundbacher, R.W., Kollberg, E.L., Lai, R., Rorsman, N., Starski, P., Stenarson, J., Streit, D.C., Zirath, H., “Cryogenic Wide-Band Ultra-Low-Noise IF Amplifiers Operating at Ultra-Low DC Power”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 51, Issue 6, Jun. 2003

[53] Fujimoto, S., Katoh, T., Ishida, T., Oku, T., Sasaki, Y., Ishikawa, T., Mitsui, Y., ”Ka-band Ultra Low Noise MMIC Amplifier Using Pseudomorphic HEMTs”, *IEEE MTT-S International Microwave Symposium Digest*, Vol. 1, pp. 17-20, Jun. 1997

[54] Pobanz, C., Matloubian, M., Nguyen, L., Case, M., Ming Hu, Lui, M., Hooper, C., Janke, P., “A High Gain, Low Power MMIC LNA for Ka-band using InP HEMTs”, *IEEE Radio Frequency Integrated Circuits (RFIC) Symposium*, pp. 149-152, 13-15 Jun. 1999

[55] Hacker, J.B., Bergman, J., Nagy, G., Sullivan, G., Kadow, C., Heng-Kuang Lin, Gossard, A.C., Rodwell, M., Brar, B., “An Ultra-Low Power InAs/AlSb HEMT Ka-band Low-Noise Amplifier”, *IEEE Microwave and Wireless Components Letters*, Vol. 14, Issue 4, pp. 156 - 158, Apr. 2004

[56] Yu-Lung Tang, Niklas Wadefalk, Mathew A. Morgan, Sander Weinreb, “Full Ka-band High Performance InP MMIC LNA Module”, *IEEE MTT-S International Microwave Symposium Digest*, pp. 81-84, Jun. 2006

[57] Pekka Kangaslahti, Todd Gaier, Michael Seiffert, Sander Weinreb, Dennis Harding, Douglas Dawson, Mary Soria, Charles Lawrance, Benjamin Hooberman, Amber Miller, “Planar Polarimetry Receivers for Large Imaging Arrays at Q-band”, *IEEE MTT-S International Microwave Symposium Digest*, pp. 89-92, Jun. 2006

[58] Gerecht, E.; Musante, C.F.; Zhuang, Y.; Yngvesson, K.S.; Goltsman, G.N.; Voronov, B.M.; Gershenzon, E.M.; ”NbN Hot Electron Bolometric Mixers - A New Technology for Low-Noise THz Receivers”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, Issue 12, pp. 2519-2527, Dec. 1999

[59] Siegel, P.H., “Terahertz Technology”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 50, Issue 3, pp. 910–928, Mar. 2002

[60] Rodriguez-Morales, F., Yngvesson, K.S., Zannoni, R., Gerecht, E., Dazhen Gu, Xin Zhao, Wadefalk, N., Nicholson, J.J., “Development of Integrated HEB/MMIC Receivers for Near-Range Terahertz Imaging”, ”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, Issue 6, pp. 2301-2311, Jun. 2006

[61] P. Sjoman, T. Ruokokoski, P. Jukkala, P. Eskelinen, “Planck Satellite 70 GHz Receiver Noise Test”, *IEEE Aerospace and Electronics System Magazine*, Vol. 16, Issue 12, pp.19-23, 2001

[62] Tuovinen, J., Hughs, N., Jukkala, P., Kangaslahti, P., Karttaavi, T., Sjoman, P., and Varis, J., ”Technology for Millimetre Wave Radiometers”, *Proceedings of the 33rd European Microwave Conference*, pp. 883-886, Munich, Oct. 2003

[63] M. Laaninen, P. Jukkala, N. Hughes, J. Varis, J. Tuovinen, “Results of the Planck 70 GHz Receiver Protoflight Model Test Campaign”, *4th Workshop on Millimetre-Wave Technology and Applications*, pp. 475-480, Espoo, Finland, 15-17 February 2006

[64] P.Sjoman, T. Ruokokoski, N.J Hughes, P. Jukkala, P Kangaslahti, S. Ovaska, P. Eskelinen, “Planck Satellite 70 GHz EBB-Version Back End Module”, *IEEE Aerospace and Electronics System Magazine*, Vol. 18, Issue 5, pp. 22-25, May 2003

[65] Maino, D., Burigana, C., Maltoni, M., et al., “ The Planck-LFI instrument: Analysis of the 1/f Noise and Implications for the Scanning Strategy” *Astronomy & Astrophysics*, 140, 383, 1999

[66] Mennella, A., Bersanelli, M., Buigana, C., et al, “PLANCK: Systematic Effects Induced by Periodic Fluctuations of Arbitrary Shape”, *Astronomy & Astrophysics*, 384, pp.736-742 , 2002

[67] A. Mennella, M. Bersanelli, C. Burigana, D. Maino, R. Ferretti, G. Morgante, M. Prina, N. Mandolesi, C. Butler, L. Valenziano, F. Villa, “Analysis of Thermally-Induced Effects in Planck Low Frequency Instrument”, *AIP Conference Proceedings* 616, pp. 229-233, 2002

[68] M. Seiffert, A. Mennella, C. Burigana, N. Mandolesi, M. Bersanelli, P. Meinhold, P. Lubin, “1/f Noise and Other Systematic Effects in the Planck-LFI Radiometers“, *Astronomy & Astrophysics*, 391, 1185-1197, 2002

[69] A. Mennella, M. Bersanelli, M. Seiffert, D. Kettle, N. Roddis, A. Wilkinson, P. Meinhold, “Offset Balancing in Pseudo-Correlation Radiometers for CMB Measurements“, *Astronomy & Astrophysics*, 410, pp.1089-1100, Nov. 2003

[70] J. Portilla, E. Artal, E. Martinez-Gonzalez, "Analysis of the 1/f-Noise Effects on the Planck Low-Frequency Instrument Receivers". *Astrophysical Letters and Communications*, Vol. 37, pp. 195-203, 2000

[71] C.G. Gentili, R. Nesti, G. Pelosi, and V. Natale, “Compact Dual–Profiled Corrugated Circular Waveguide Horn”, *Electronics Letters*, Vol. 36, Issue 6, pp. 486-487, Mar. 2000

[72] F. Villa, M. Sandri, N. Mandolesi, R. Nesti, M. Bersanelli, A. Simonetto, C. Sozzi, O. D'Arcangelo, V. Muzzini, A. Mennella, P. Guzzi, P. Radaelli, R. Fusi, E. Alippi, “High Performances Corrugated Feed Horns for Space Applications at Millimetre Wavelengths”, *Experimental Astronomy,* Vo. 14, pp. 1-15, 2002

[73] L. Valenziano, M. Bersanelli, R. C. Butler,1 F. Cuttaia, N. Mandolesi, A. Mennella, G. Morigi, G. Morgante, M. Sandri, L. Terenzi, and F. Villa, "The 4K Reference Load for the Planck Low Frequency Instrument", AIP Conference Proceedings, Vol. 616, Issue 1, pp. 219-223, May 2002

[74] Cuttaia, Francesco; Valenziano, Luca; Bersanelli, Marco; Butler, Reginald C.; D'Arcangelo, Ocleto; Kettle, Danielle; Levin, Steven; Mandolesi, Nazareno; Mennella, Aniello; Morgante, Gianluca; Morigi, Gabriele; Roddis, Neil; Simonetto, Alessandro; Terenzi, Luca; Tomasi, Maurizio; Villa, Fabrizio, "Analysis of the Radiometer-reference Load System on Board the Planck/LFI Instrument", *Nuclear Instruments and Methods in Physics Research Section A*, Vol. 520, Issue 1-3, pp. 396-401, 2004

[75] L. Valenziano, F. Cuttaia, A. De Rosa, M. Sandri, L. Terenzi, N. Mandolesi, M. Bersanelli, A. Mennella, M. Tomasi, A. Simonetto, "Design, Manufacturing and Testing of the Flight Model of the 4K Reference Load Unit for the Low Frequency Instrument Onboard the Planck Satellite", *4th Workshop on Millimetre-Wave Technology and Applications*, pp. 181-186, Espoo, Finland, 15-17 February 2006

[76] G. Morgante, D. Barber, P. Bhandari, R.C. Bowman, P. Cowgill, D. Crumb, T. Loc, A. Nash, D. Pearson,, M. Prina, A. Sirbi, M. Schemlzel, R. Sugimura and L.A. Wade, "Two Hydrogen Sorption Cryocoolers for the Planck Mission", *AIP Conference Proceeding*, Vol. 616(1), pp. 298-302, May 2002

[77] J.P. Pascual, B. Aja, M.L. de la Fuente, E. Artal, "Radiometer Simulation using RF Platforms", *Proceedings of the International Workshop on Electronics and System Analysis*, pp. 119-122. U.P.V/E.H.U. Fac. de Ciencia y Tecnología, Bilbao, España, Oct. 2004

[78] J.P. Pascual, B. Aja, M.L de la Fuente, T. Pomposo, E. Artal., " System Simulation of a Differential Radiometer Using Standard RF-Microwave Simulators", *Simulation, Transactions of the Society for Modeling and Simulation International*, Vol. 81, Issue 11, pp. 735-755, Nov. 2005

[79] B. Aja, M.L. de la Fuente, J.P. Pascual, A. Mediavilla, E. Artal, "Low Noise Monolithic Ka-Band P-HEMT Amplifier for Space Applications", *Proceeding of the European Gallium Arsenide and other semiconductors Applications Symposium (GAAS 2001)*, pp. 85-88, London-England, Sept. 2001

[80] B. Aja, M.L. de la Fuente, J.P. Pascual, A. Mediavilla, M. Cryan, E. Artal, "Q-Band Monolithic GaAs PHEMT Low Noise Amplifiers: Comparative Study of Depletion and Enhancement Mode Transistors", *Proceedings of the European Gallium Arsenide and other semiconductors Applications Symposium (GAAS 2002)*, pp. 53-56. Milan- Italia, Sept. 2002

[81] Raimond S. Pengelly, "Monolithic Microwave Integrate Circuits – Part I", *IEEE MTT-S Newsletter*, pp. 39-48, Winter 1989

[82] R. Goyal, "Monolithic Microwave Integrated Circuits", Artech House, Inc. Norwood, Massachusetts, Estados Unidos, 1989

[83] H. Fukui, "Optimal Noise Figure of Microwave GaAs MESFET´s", *IEEE Transactions on Electron Devices,* Vol. 26, Issue 7, pp. 1032-1037, Jul. 1979

[84] H. Fukui, "Design of Microwave GaAs MESFET´s for Broad-Band Low Noise Amplifiers", *IEEE Transactions on Microwave Theory and Technique*, Issue 7, pp. 643-650, Jul. 1979

[85] C.R. Poole and D.K. Paul, "Optimum Noise Measure Terminations for Microwave Transistor Amplifiers", *IEEE Transactions on Microwave Theory and Techniques*, pp.1254-1257, Nov. 1985

[86] J. Engberg, "Simultaneous Input Power Match and Noise Optimization Using Feedback", *Proceedings of the 4th European Microwave Conference*, pp. 385-389, 1974

[87] Iversen, "The Effect of Feedback on Noise Figure", Proceedings of the IEEE, Vol. 63, Issue 3, pp. 540- 542, Mar. 1975

[88] L. Besser, "Stability Consideration of Low-Noise Transistor Amplifiers with Simultaneous Noise and Power Match," *IEEE MTT-S International Microwave Symposium Digest*, pp. 327-329, 1975

[89] Lehmann, R.E.; Heston, D.D, "X-Band Monolithic Series Feedback LNA", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 33, Issue 12, pp. 1560-1566, Dec.1985

[90] K.B. Niclas, "Noise in Broad-Band GaAs MESFET Amplifiers with Parallel Feedback", *IEEE Transactions on Microwave Theory and Techniques,* Vol. 30, pp. 63-70, Jan. 1982

[91] M.L. Edwards and J.H. Sinsky, "A New Criterion for Linear 2-Port Stability Using a Single Geometrically Derived Parameter", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 40, Issue 12, pp. 2303-2311, Dec. 1992

[92] Inoue, Y.; Sato, M.; Ohki, T.; Makiyama, K.; Takahashi, T.; Shigematsu, H.; Hirose, T., "A 90-GHz InP-HEMT Lossy Match Amplifier with a 20-dB Gain Using a Broadband Matching Technique", *IEEE Journal of Solid-State Circuits*, Vol. 40, Issue 10, pp. 2098– 2103, Oct. 2005

[93] K.B. Niclas, "GaAs MESFET Feedback Amplifiers: Design Considerations and Characteristics", *Microwave Journal*, pp. 39-48 & 85, Mar. 1980

[94] K.B. Niclas, W. T. Wilser, R. B. Gold & W. R. Hitchens, "The Matched Feedback Amplifier: Ultrawide-Band Microwave Amplification with GaAs MESFETs", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 28, pp. 285-294, Apr. 1980

[95] K.B. Niclas, "Multi-Octave Performance of Single-Ended Microwave Solid-State Amplifiers", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 32, Issue 8, pp. 896-908, Aug. 1984

[96] Wolfgang J. R. Hoefer, "Closed-Form Expressions for the Parameters of Finned and Ridged Waveguides", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 30, pp. 2190-2194, Dec. 1982

[97] Sammy Kayali, George Ponchak, Roland Shaw "GaAs MMIC Reliability Assurance Guideline for Space Applications" *Jet Propulsion Laboratory, California Institute of Technology Pasadena*, California, JPL Publication 96-25, 15 Dec. 1996

[98] OMMIC "GaAs IC Design Manuals – ED02AH", 1997

[99] Robert Soares, "GaAs MESFET Circuit Design", Artech House, Inc. Norwood, Massachusetts, Estados Unidos, 1988

[100] B. Aja, M.L de la Fuente, J.P. Pascual, M. Detratti, E. Artal., "GaAs PHEMT Broadband Low Noise Amplifier for Millimeter Wave Radiometer", *Microwave and Optical Technology Letters (Wiley Periodicals, Inc)*, Vol. 39, Issue 6, pp. 475-479, Dec. 2003

[101] M. C. Maya, A. Lázaro, P. de Paco, L. Pradell, "A Method for Characterizing Coplanar Waveguide-to-Microstrip Transitions, and its Application to the Measurement of Microstrip Devices with Coplanar Microprobes", *Microwave and Optical Technology Letters*, Vol. 39, Issue 5, pp. 373-378, Oct. 2003

[102] M. L. Edwards, S. Cheng, J. H. Sinsky, "A Deterministic Approach for Designing Conditionally Stable Amplifiers", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 43, Issue 7, pp.1567-1575, Jul. 1995

[103] K. W. Eccleston, "Design Formulae for Microwave Amplifiers Employing Conditionally-Stable Transistors", *IEICE Trans. Electron.*, Vol.E82-C, Issue 7, pp. 1054-1060, Jul. 1999

[104] G. D. Vendelin, A. M. Pavio, U. L. Rohde, "Microwave Design Circuit – Using Linear and Nonlinear Techniques", John Wiley and Sons, Inc. 1990

[105] G. Gonzalez, " Microwave Transistor Amplifiers – Analysis and Design", Capitulo 3, Segunda Edición, Pentice-Hall, Inc. 1984

[106] E. Artal, M. Detratti, C. Palacios, J. P. Pascual, "Tecnología de Montaje de Circuitos de Bajo Ruido en la Banda de Milimétricas", *Proceedings URSI 2001*, Madrid, 2001

[107] Kai Chang, Fwu-jih Hsu, John Berenz and Ken Nakano, "Find Optimum Substrate Thickness for Millimeterwave GaAs MMICs", *Microwaves & RF*, pp. 123-128, 1984

[108] Vendelin GD, "Limitations on Stripline Q". *Microwave Journal*, pp. 63-69. May 1970

[109] T.C. Edwards, "Foundations for Microstrip Design". 2nd Edition, Chichester, England: John Wiley & Sons, 1992

[110] H.A. Wheeler, "Transmission-Line Properties of Parallel Strips Separated by a Dielectric Sheet". *IEEE Transactions on Microwave Theory and Techniques*, Vol. 13, pp. 172-185, Mar. 1965

[111] S. Mao, S. Jones and G.D. Vendelin, "Millimeter-Wave Integrated Circuits". *IEEE Transactions on Microwave Theory and Techniques*, Vol. 16, Issue 7, pp. 455-461, Jul. 1968

[112] Inder Bahl and Praskash Bhartia, "Microwave Solid State Circuit Design", Second Edition, John Wiley & Sons, Inc. New Jersey, USA 2003

[113] S. Rosloniec, "Design of Stepped Transmission Line Matching Circuits by Optimization Methods", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 42, Issue 12, pp. 2255-2260, Dec. 1994

[114] AN-A001, "Notes on Choke Network Design" AVANTEK

[115] G. Robert H. Caverly, "Characteristic Impedance of Integrated Circuit Bond Wires", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 34, Issue 9, pp. 982-984, 1986

[116] N. Otegi, J.M. Collantes, M. Sayed, "Calibrated Noise Figure Measurements in Vector Network Analyser", *IEE Electronic Letters*, Vol. 41, Issue 18, pp. 999-1000, Sept. 2005

[117] A. Collado, J.M. Collantes, L. de la Fuente, N. Otegi, L. Perea, M. Sayed, "Combined Analysis of Systematic and Random Uncertainties for Different Noise-Figure Characterization Methodologies", *IEEE MTT-S International Microwave Symposium Digest*, 2003

[118] M. Detratti, B. Aja, J.P. Pascual, L. de la Fuente and E. Artal "Millimeter Wave Microstrip Broadband Bandpass Filters Design and Test", *Proceedings of the 32nd European Microwave Conference*, 573-575, 2002

[119] "IQE supplies InP and metamorphic wafers", *Compound Semiconductor*, Vol. 7. Nº4, pp. 25, 2001

[120] M. V. Aust, T.W. Huang, H.. Wang, D.C.W. Lo, R. Lai, M. Biendenbender, and C.C. Yang "Ultra Low Noise Q-Band Monolithic Amplifiers Using InP- and GaAs-Based 0.1 μm HEMT Technologies", *IEEE Microwave and Millimeter-Wave Monolithic Circuits Symposium*, pp. 89-92, 1996

[121] Gough, R.G. Sinclair, M.W., "Low Noise, Indium Phosphide Monolithic Microwave Integrated Circuit Amplifiers for Radioastronomy", *Microwave Conference, Asia-Pacific*, pp. 668 –672, 2000

[122] M.J. Delaney, R.C. Wong, T.T. Lee, B.M. Paine, "GaAs PHEMT and InP HEMT MMIC Requirements for Satellite Based Communications Systems", GaAs Mantech 2001

[123] Y.C.Chou, D. Leung, R. Lai, J. Scarpulla, M. Biedenbender, R. Grundbacher, D. Eng, P.H. Liu, A. Oki and DC. Streit, "High Reliability Non-Hermetic 0.1μm GaAs Pseudomorphic HEMT MMIC Amplifiers", *IEEE Gallium Arsenide Integrated Circuit (GaAs IC) Symposium, 2001. 23rd Annual Technical Digest*, pp. 170-173, 2001

[124] B. J. Jang, I. B. Yom, and S. P. Lee, "Q- and V-band MMIC Low-Noise Amplifiers", Microwave Journal, vol.45, pp. 74-84, Jun. 2002

[125] Pedro de Paco Sánchez, "La Misión Planck. Diseño De Detectores de Banda Ancha y Alta Sensibilidad en Banda Milimétrica". Tesis Doctoral. Departamento de Teoría de la Señal y Comunicaciones, Universidad Politécnica de Cataluña. 2003

[126] David Rubin, David Saul, "mm Wave MICs Use Low Value Dielectric Substrates", Microwave Journal, pp. 35-39, Nov. 1976.

[127] Yi-chi Shih, Thuy-Nhung Ton, and Long Q. Bui, "Waveguide-to-Microstrip Transitions for Millimeter-Wave Applications", *IEEE MTT-S International Microwave Symposium Digest*, pp. 473-475, 1988

[128] Frank J. Villegas, D. Ian Stones, and H. Alfred Hung, "A Novel Waveguide-to-Microstrip Transition for Millimeter-Wave Module Applications", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, Issue 1, Jan. 1999

[129] Noriaki Kaneda, Yongxi, and Tatsuo Itoh, "A Broad-band Microstrip-to-Waveguide Transition Using a Quasy-Yagi Antenna", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, Issue 12, Dec. 1999

[130] D.R. Singh and C.R. Seashore, "Straightforward Approach Produces Broadband Transitions", Microwaves&RF, pp.113-118, Sept. 1984

[131] B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, J. L. Cano "Three Port Stability Analysis of Broadband Millimetre Wave MMIC Amplifier", *Proceeding of the 1st European Microwave Integrated Circuits Conference, EuMIC*, Manchester, UK, pp.399-402, Sept. 2006

[132] John F. Bohem and William G. Albright, "Unconditional Stability of a Three- Port Network Characterized with S-Parameters", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 35, Issue 6, pp. 582-586, Jun. 1987

[133] E.L. Tan "Simplified Graphical Analysis of Linear Three-Port Stability", *IEE Proceedings -Microwave Antennas Propagation*, Vol. 152, Issue 4, pp. 209-213, Aug. 2005

[134] G. Matthaei, L. Young and E.M.T. Jones, "Microwave filters, Impedance-Matching Networks, and Coupling Structures", Norwood, M.A., USA, Artech House, 1964

[135] J.P. Pascual, B. Aja, M.L. de la Fuente, M. Detratti and E. Artal, "Equalize Gain in Millimeter-Wave Amplifiers", *Microwaves& RF*, Vol. 44, Issue 4, pp. 61-68, Apr. 2005

[136] José T. Pelayo Carral, "Circuitos de Protección y Polarización de Transistores HEMT de Microondas", Proyecto fin de carrera, Dpto. Ingeniería de Comunicaciones, Universidad de Cantabria, Julio 2002

[137] Aja B., de la Fuente L., Pascual J.P., Artal E., "Técnica de Mejora del Ancho de Banda Efectivo en el Módulo Posterior del Radiómetro Planck", *URSI 2004 XIX Simp. Nacional, Actas del Simposium*, pp. 93, Universitat Ramon Llull (Barcelona), Sept. 2004

[138] B. Aja, E. Artal, M.L. de la Fuente, J.P. Pascual, "Effective Bandwidth Improvement Technique Based On Mismatch Analysis", *Conference Proceedings 36th European Microwave Conference*, EuMC, Manchester, UK, pp. 1501-1504, Sept. 2006

[139] W. Menzel, J. Kassner, U. Goebel, "Innovative Packaging and Fabrication Concept for a 28 GHz Communications Front-End", *IEICE, Trans. Electron*. Vol. E82 C, N11, Nov. 1999

[140] Application Note 57-1, "Fundamentals of RF and Microwave Noise Figure Measurements", Agilent Technologies.

[141] Application Note 57-2, "Noise Figure Measurement Accuracy – The Y-Factor Method", Agilent Technologies

[142] Ana Collado Garrido, "Medida de Ruido en Bandas Milimétricas. Estudio de la Incertidumbre", Trabajo fin de carrera. Ingeniería de Telecomunicación. 9 Julio 2002

[143] V. Adamian and A. Uhlir, "A Novel Procedure for Receiver Noise Characterization", *IEEE Trans. Instrum. Meas*., Vol. 22, pp. 181–182, 1973

[144] B. Aja, J.P. Pascual, M.L. de la Fuente, J. Gallegos, E. Artal, "A New Method to Obtain Total Power Receiver Equivalent Noise Temperature", *Proceedings of the 33rd European Microwave Conference*, pp. 355-358, ICM, Munich, Germany, Oct. 2003

[145] P. Drexler, "Noise Measurement Using the Y Factor, a Technique for Characterization of Narrowband Sources", *RF Design Feature*, pp. 88-91, Oct. 1983

[146] J.E. Fernandez, "A Noise-Temperature Measurement System Using a Cryogenic Attenuator", *TMO Progress Report 42-135*, pp. 1-9, Nov. 1998

[147] R.J. Hoyland, "A Wideband 180º Microwave Phase Shift Structure", *Patent No: PCT ESO 1/00135*, 2000

[148] R.J. Hoyland, "A New MMIC, Wideband 180º Phase Switch Design for Millimeter Wave Applications", *Proceedings of 3rd ESA Workshop on Millimetre Wave Technology and Applications*, Espoo, Finland, pp. 305-310, May 2003.

[149] E. W. Wollack, M. W. Pospieszalski, "Characteristics of Broadband InP Millimeter-Wave Amplifiers for Radiometry", *IEEE MTT-S International Microwave Symposium Digest*, Vol. 2, pp. 669-672, Jun. 1998

[150] N.R. Erickson, R.M. Grosslein, R.B. Erickson, S. Weinreb, "A cryogenic Focal Array for 85-115 GHz Using MMIC Preamplifiers", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, Issue 12, pp. 2212-2219 , Dec. 1999

[151] J. Tuovinen, M. Bersanelli, and N. Mandolesi, "Ultra Low-Noise and High Stability Receivers of Planck LFI", *Astronomical and Astrophysics. Transactions*, Vol. 19, pp. 551-558, 2000

[152] Saito, T., Oohashi, Y., Kurihara, H., Hirachi, Y., Kasuga, T., Miyazawa, K., "A Cryogenic 43-GHz-Band Low-Noise Amplifier for Radio Astronomy", *IEEE MTT-S International Microwave Symposium Digest*, Vol. 3, pp. 853-856, 13-15 Jun. 1989

[153] Weinreb, S., Pospieszalski, M.W., Norrod, R., "Cryogenic, HEMT, Low-Noise Receivers for 1.3 to 43 GHz Range", *IEEE MTT-S International Microwave Symposium Digest*, Vol. 2, pp. 945-948, 25-27 May 1988