Circular waveguide for Low Loss Transmission of Microwave and mm-Wave signals

Circular to Rectangular Waveguide Transitions

Easy to Manufacture and Very High Performance Microwave or Millimeter Wave Horn Antennas

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Why do we need circular waveguide?

1. For low cost and low loss long distance conduction of microwave and mmwave signals

2. Most antenna feedhorns are circular so they produce a fully symmetrical pattern

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Brief History of Waveguides

- Theoretically predicted by Lord Rayleigh in 1897 but then forgotten
- 1933 - 1937 waveguides simultaneously and independently re-discovered by
  - George Southworth, B.S.T.J. April 1936
  - G. Southworth patent applications 1933
  - Carson, Mead, Schelkunoff B.S.T.J. April 1936
  - Wilmer Barrow, Proc IRE Oct. 1936

Patented Sept. 13, 1938

2,129,711

UNITED STATES PATENT OFFICE

2,129,711

GUIDED TRANSMISSION OF ULTRA HIGH FREQUENCY WAVES

George Clark Southworth, Ridgewood, N. J., assignor to American Telephone and Telegraph Company, a corporation of New York

Application March 16, 1933, Serial No. 661,154

70 Claims. (Cl. 178—44)

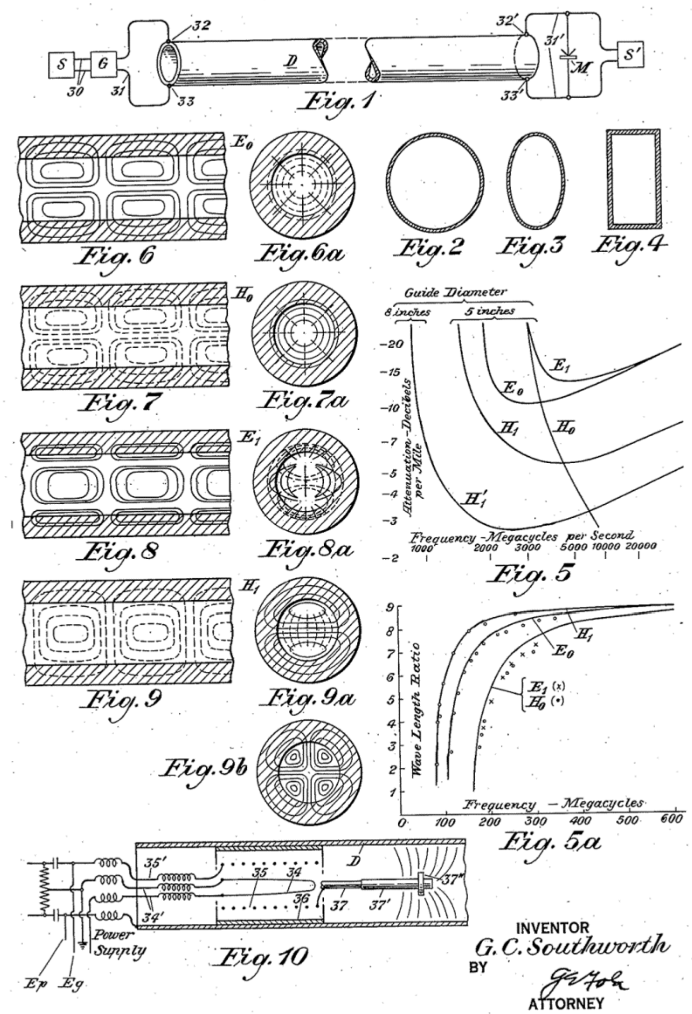
An object of my invention is to provide a new and improved system for the transmission of electrical effects from one place to another place at a distance therefrom by means of electromagnetic waves associated with a dielectric guide extending between the two places. Another object of my invention is to provide for signaling along such a guide by means of such waves. Another object is to provide for the generation of high frequency electric conduction currents in a suitable medium and the application of their energy to generate corresponding "displacement" current waves for transmission along a guide of dielectric material. An object complementary to the foregoing is to provide for the translation of the energy of received displacement currents in a dielectric guide into conduction currents in associated receiving apparatus. Still another object is to provide suitable apparatus and a proper method so that electric waves may be transmitted along a dielectric guide without excessive dissipation of their energy in the guide or in the medium adjacent thereto. In some examples of my invention the guide employed may be partly dielectric and partly conductive.

All these objects and various other objects and section on the line 9 of Fig. 8; Fig. 10 is a diagrammatic sectional view of certain testing apparatus for the standing waves in connection with Fig. 8; Fig. 11 is a curve diagram that extends the showing of Fig. 5 to different diameters of wave guides and to the case of composite wave guides each made up of a dielectric body surrounded by a metallic sheath; Fig. 12 is a set of diagrams for such a composite wave guide corresponding otherwise with Fig. 6; Fig. 13 is a diagram of sending end signaling apparatus for a dielectric guide; Fig. 14 is a corresponding diagram for the receiving end; Fig. 15 is a plan view of a generator and coupling for sending waves in a dielectric guide; Fig. 16 is a corresponding side elevation; Fig. 17 is a circuit diagram for the apparatus of Figs. 15 and 16; Fig. 18 is a section showing sending end apparatus alternative to that of Figs. 15 and 16; Fig. 19 shows still another alternative form of such apparatus; Fig. 20 is a diagram showing receiving end apparatus employing a detector; Fig. 21 is a diagrammatic end elevation showing how one or more detector units may be connected in the system of Fig. 20; Fig. 22 is a modification as compared with Fig. 20 and shows an adjustable inductive coupling; Fig.

Sept. 13, 1938. G. C. SOUTHWORTH 2,129,712

TRANSMISSION OF ENERGY EFFECTS BY GUIDED ELECTRIC WAVES IN A DIELECTRIC MEDIUM

Filed Dec. 9, 1933 5 Sheets-Sheet 1



Bell Labs Experiments and Development of Practical Low Loss Waveguide

Need: carry thousands of telephone channels for miles

Goal: 2dB per mile

Findings:

- circular waveguide has lower loss than rectangular
- overmoded (large dia) waveguide had the lowest loss
- full duplex achieved by cross polarization

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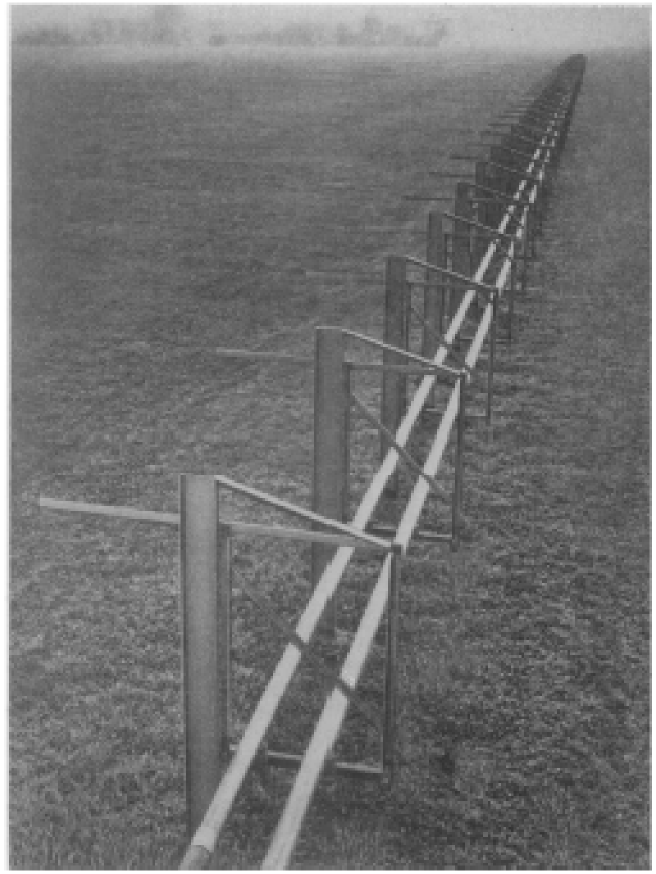

4.75 inch ID, 5 inch OD waveguides, 875 feet long. (before 1934)

Measured loss was 2dB / mile at 9Kmc

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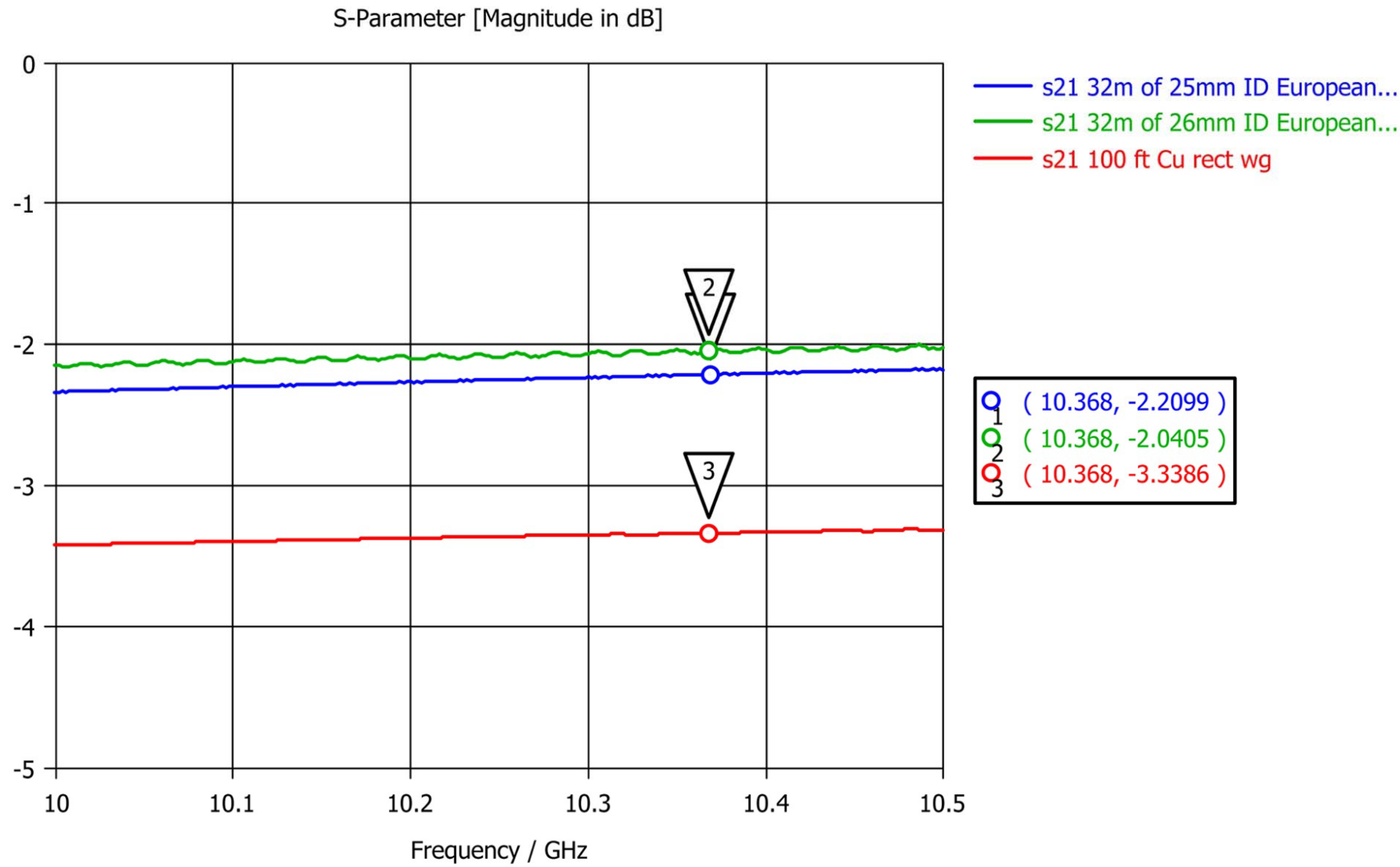

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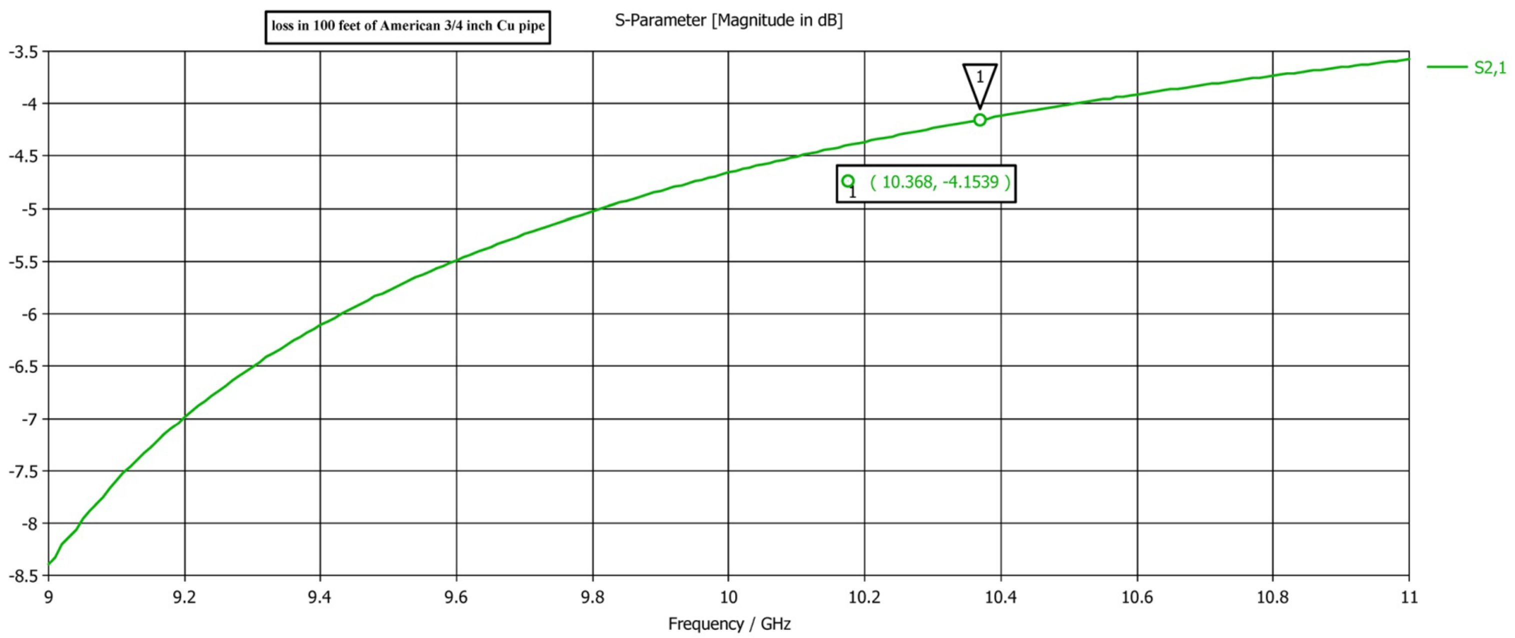

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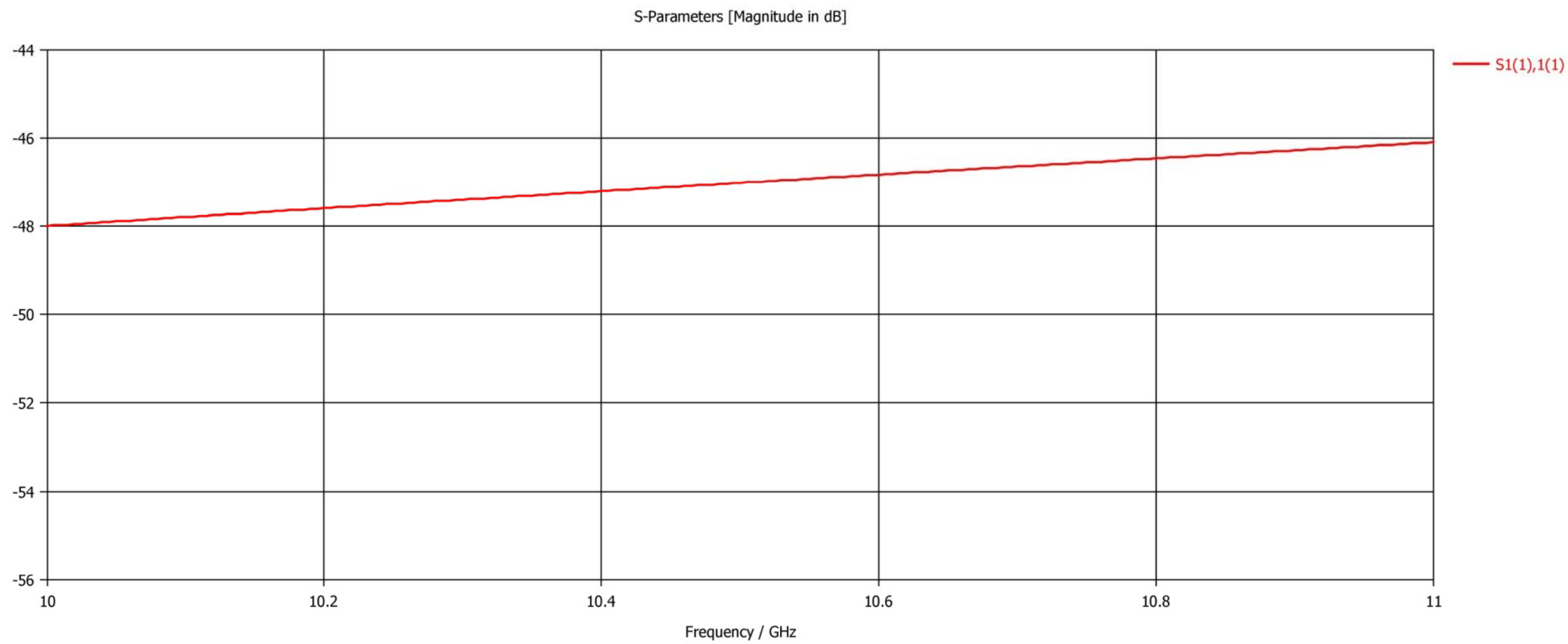

s11 of 2in ID Cu circular wg 10ft long

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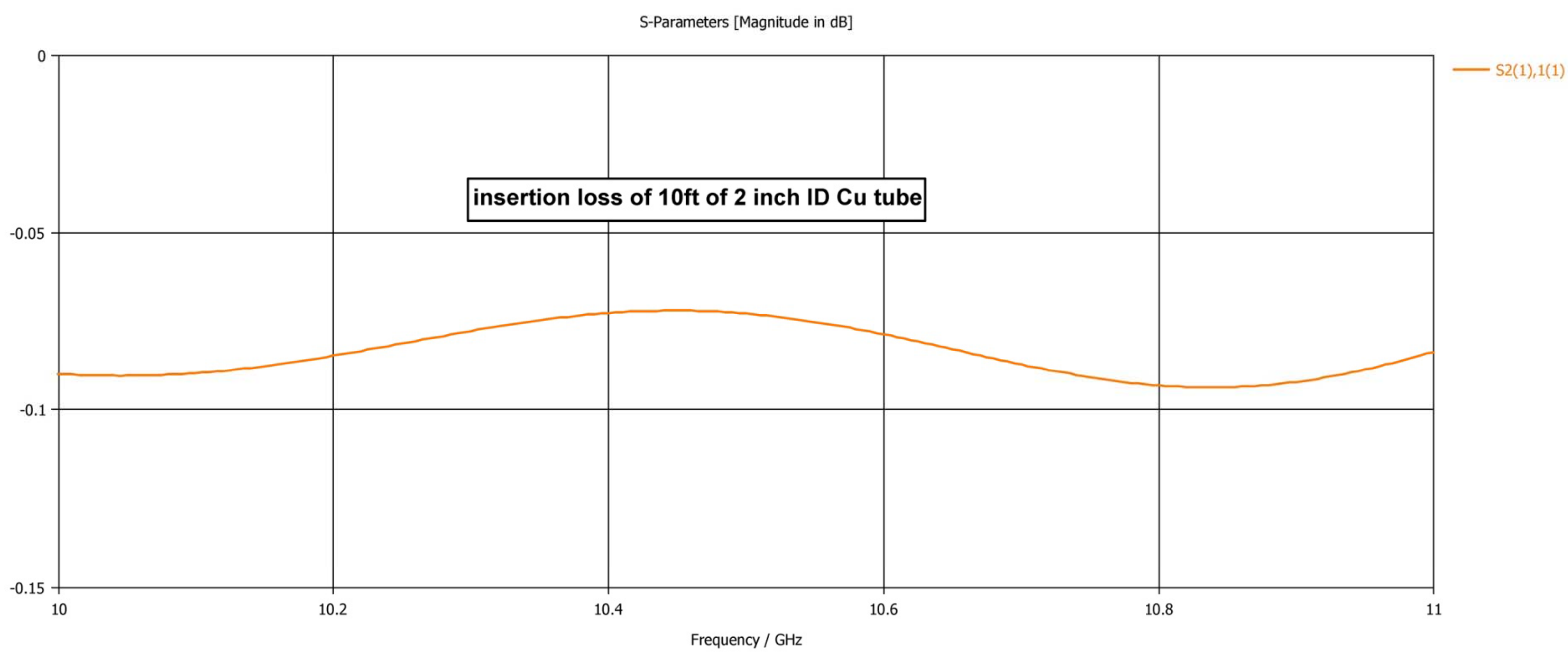

insertion loss of mode 1 in a 2in ID Cu circular wg 10ft long

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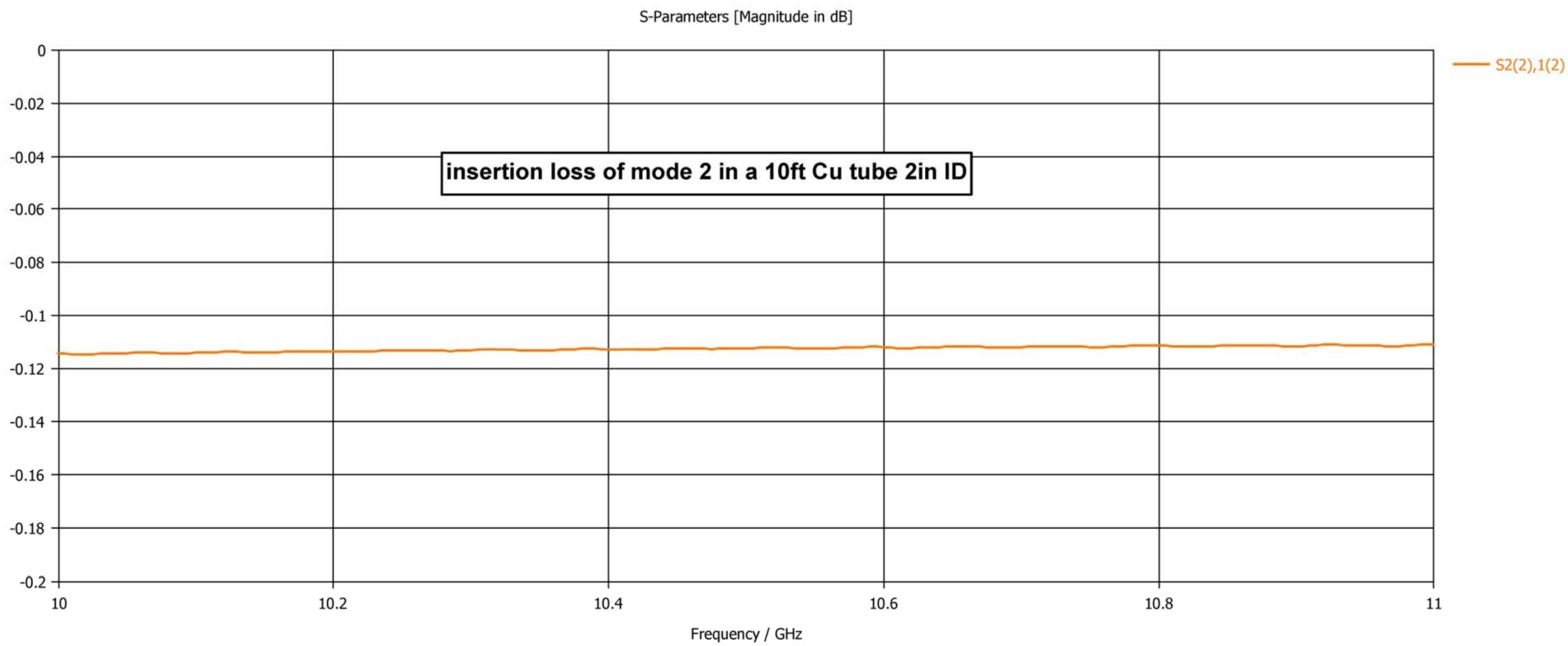
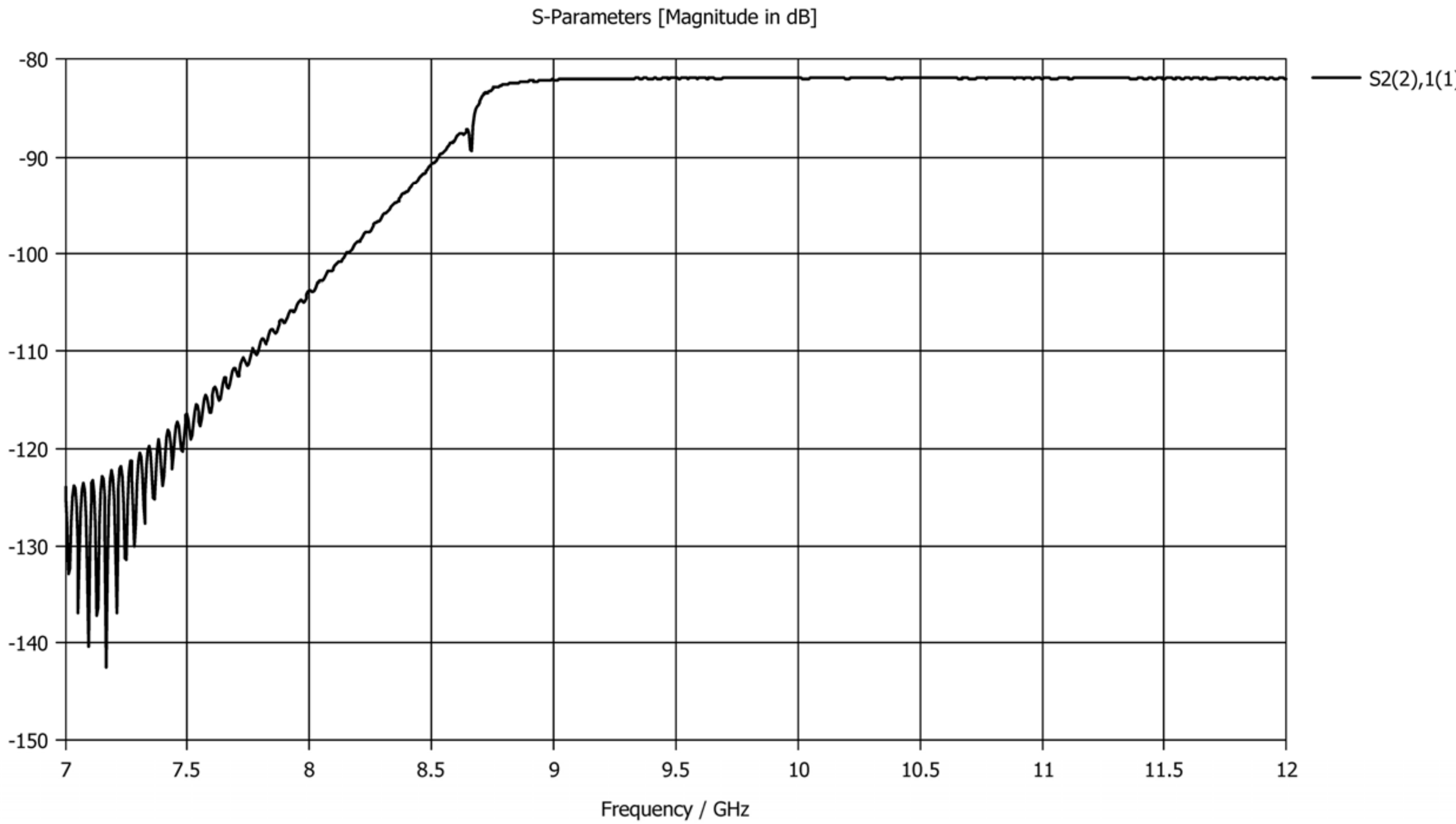


insertion loss of mode 2 in 2in ID Cu circular wg 10ft long



long tapered transition between 0.8in and 2in Cu waveguides
s21 of conversion of mode 2 to mode 1

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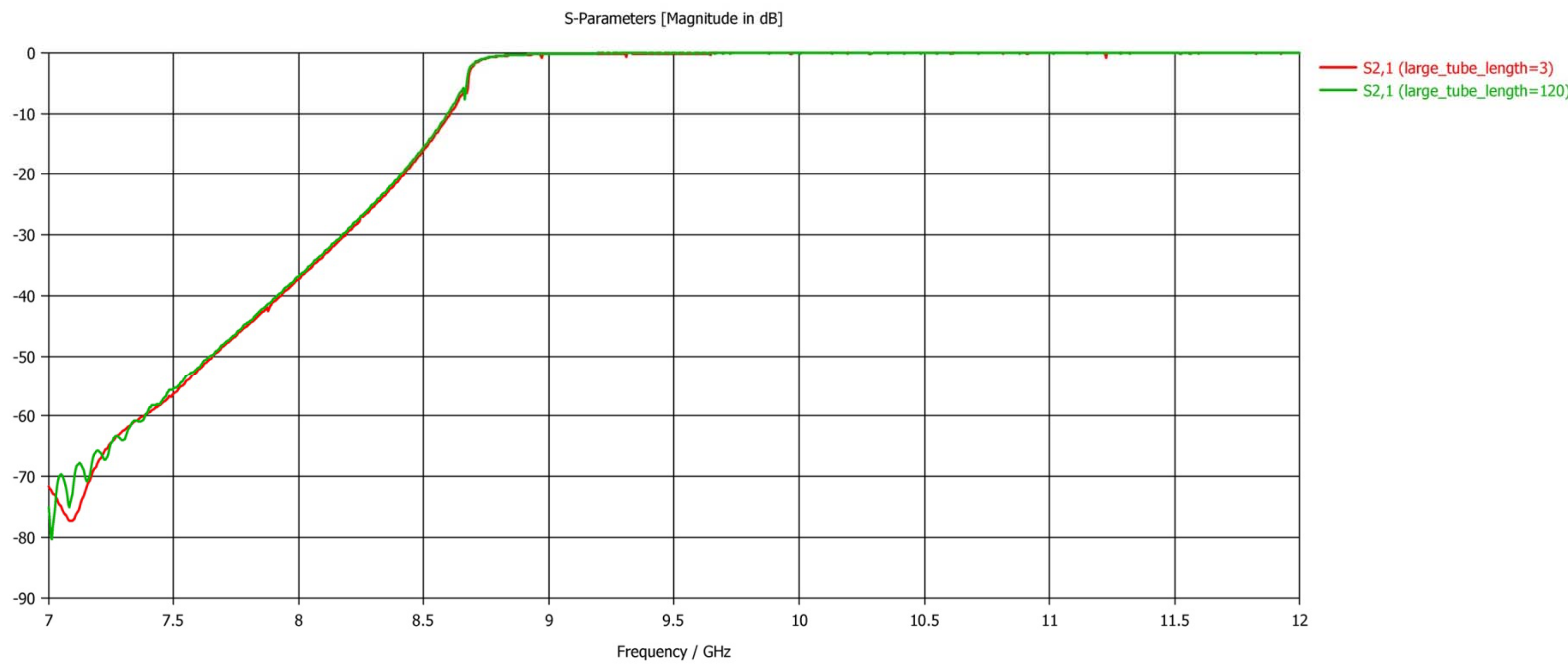

s21 of long tapered transition with short and long waveguides

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Pros and Cons:

- If you use a diameter that does not support any higher modes, then you do not need to eliminate those or phase them out at the end of your waveguide run.

- If you use large diameter circular waveguide then the loss will be much lower. You will need to get rid of the higher modes at the end.

You can taper between two diameters.

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Connecting the Circular Waveguide to your Circuits

circular to coax: a simple coaxial probe in the sidewall ahead of a short.

wideband circular to rectangular waveguide:
- simple handmade transitions for experimenting
- complex high performance broadband transitions require electroforming or casting

narrowband high performance transitions
- traditionally required complex machining
- new easy to manufacture design first published by this author in 2012

new broadband easy to manufacture design by this author shown in this presentation

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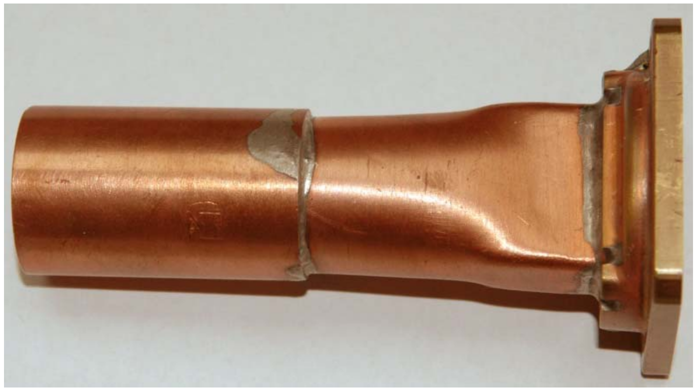
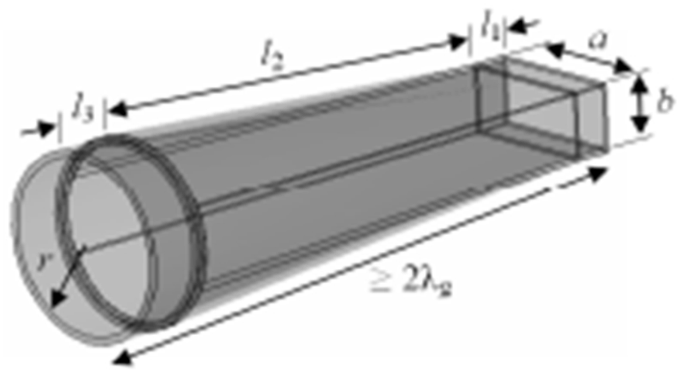
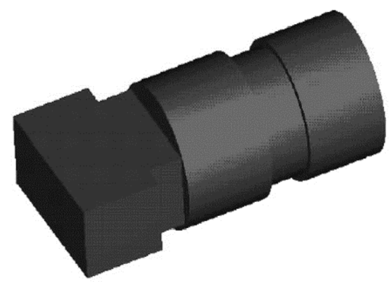


easy transition 17dB RL

Norm Wilson, not measured



Munir and Musthofa, 2011



U. Rosenberg, J. Bornemann, and K. Rambabu, 2002: Compact rectangular-to-circular waveguide transformer with two transformer sections and a circular matching section

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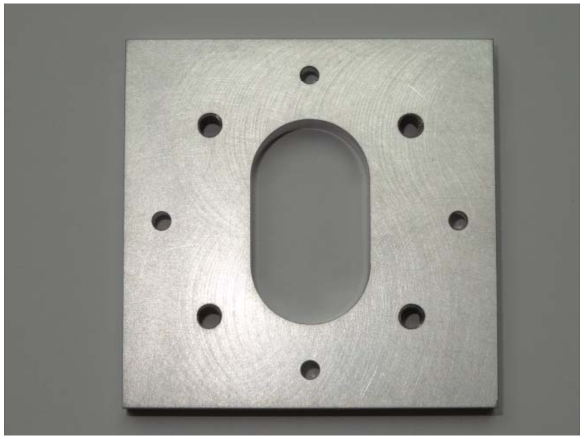

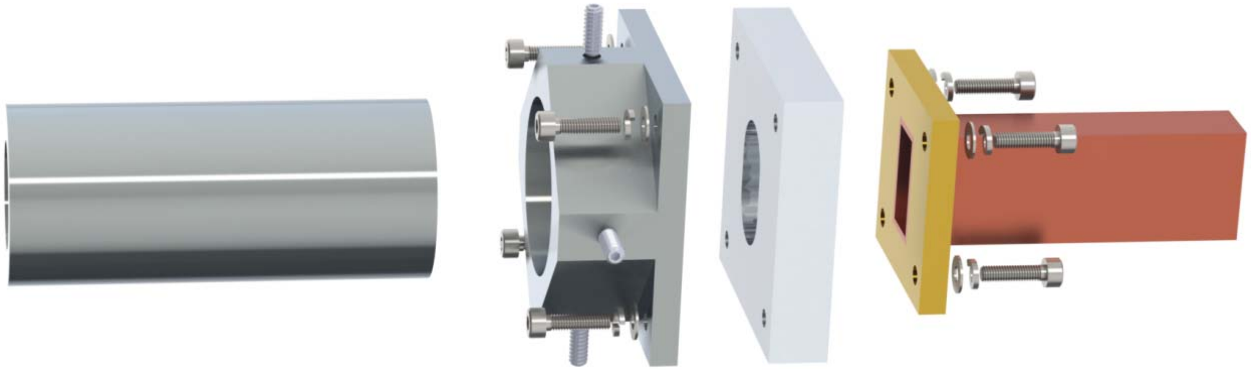

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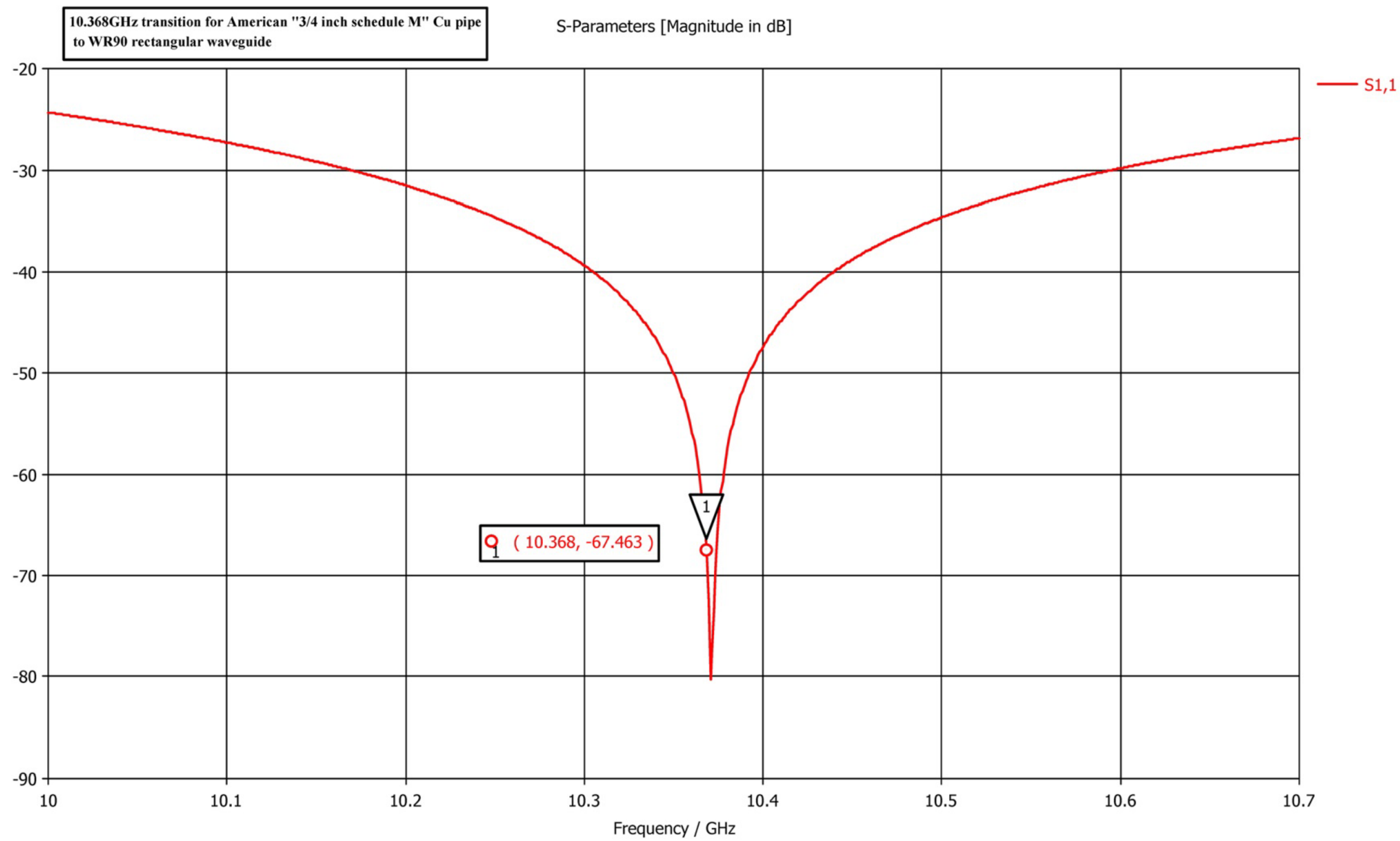

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Dual mode extremely high performance horn feeds for offset dishes with built-in transition to standard rectangular waveguide

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The Potter Horn was discovered by accident at JPL in 1961.

When the patent was filed in 1962, the drawing had an additional chamber to adjust the phase of the generated TM11 mode with respect to the dominant TE11 mode. The goal is to have both modes combine right at the mouth of the flared horn.

Pickett simplified the horn for ease of fabrication by simply using the length of the flared horn to create the correct phasing.

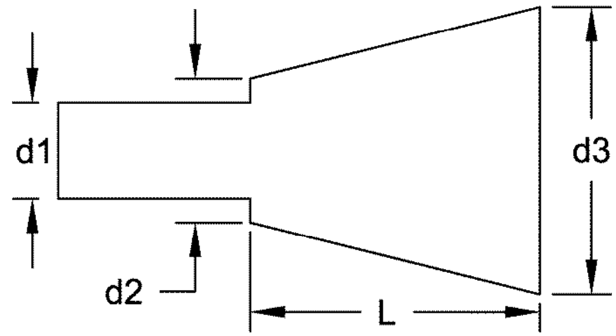
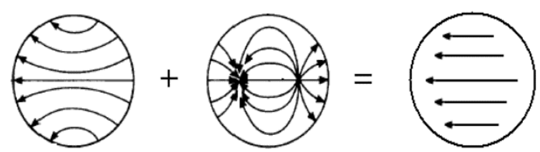


Diagram of a Pickett-Potter dual mode horn



TE11 TM11 mouth of horn

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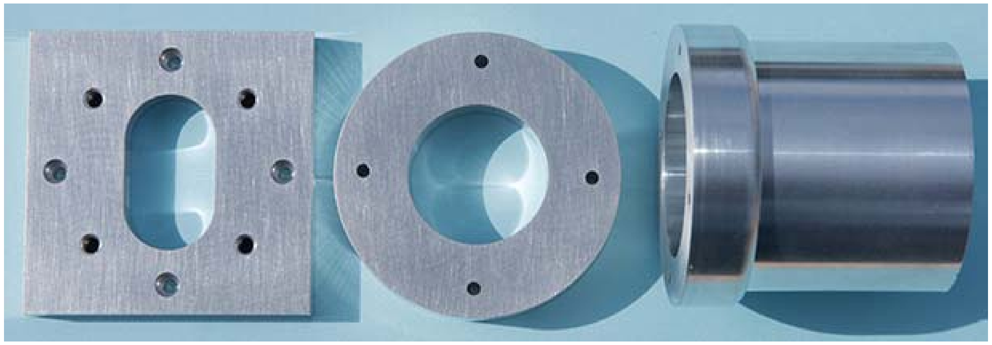

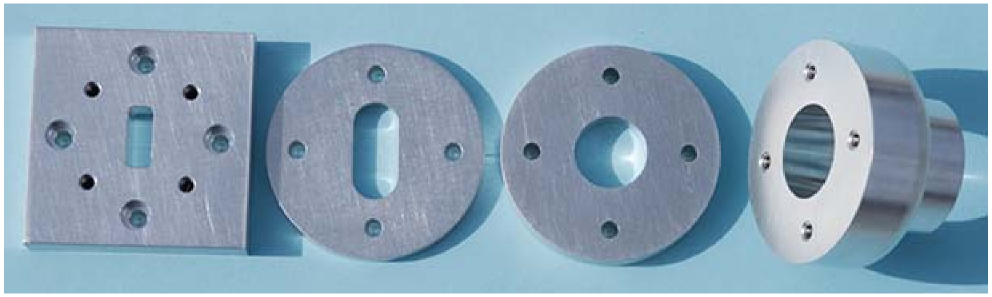

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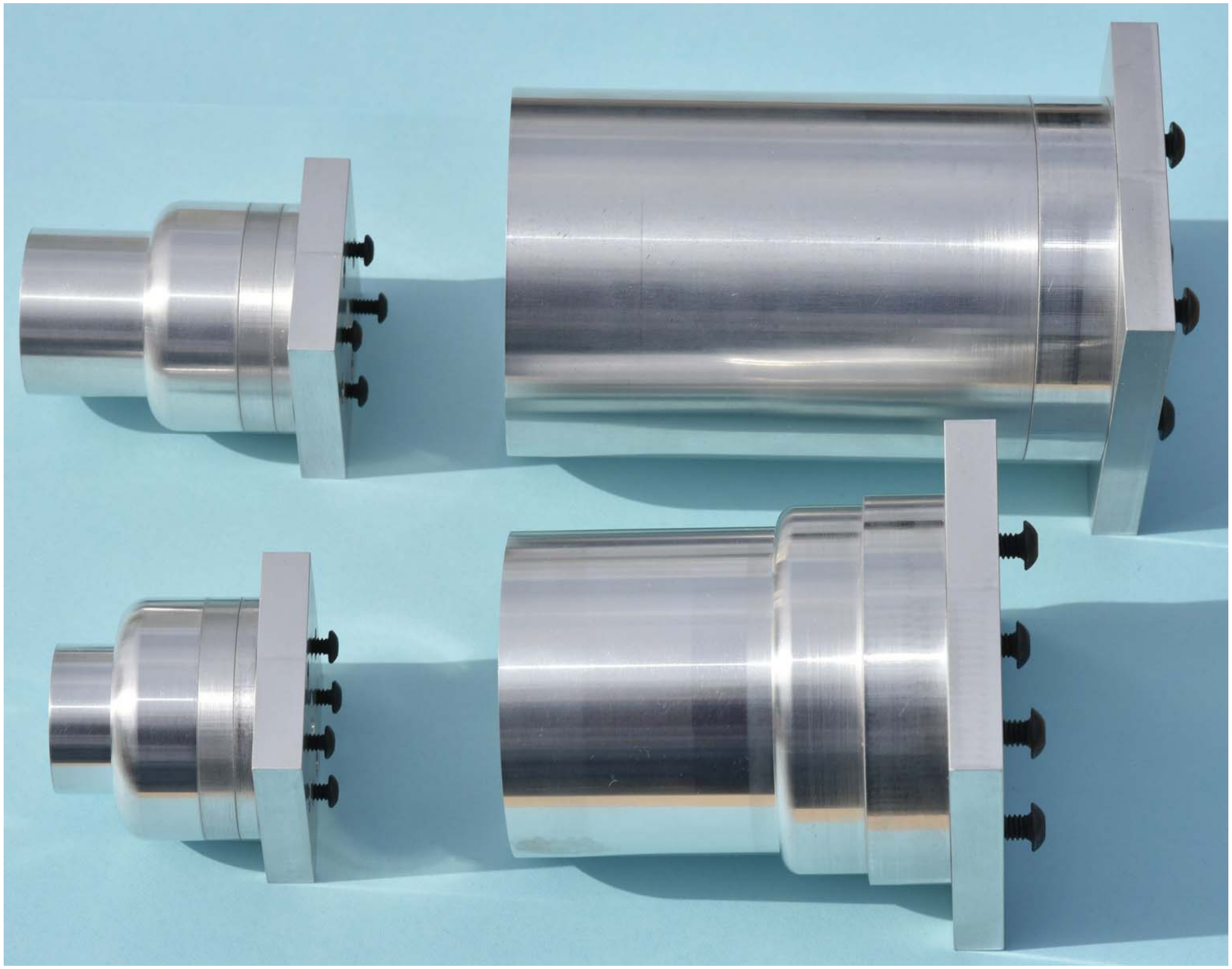

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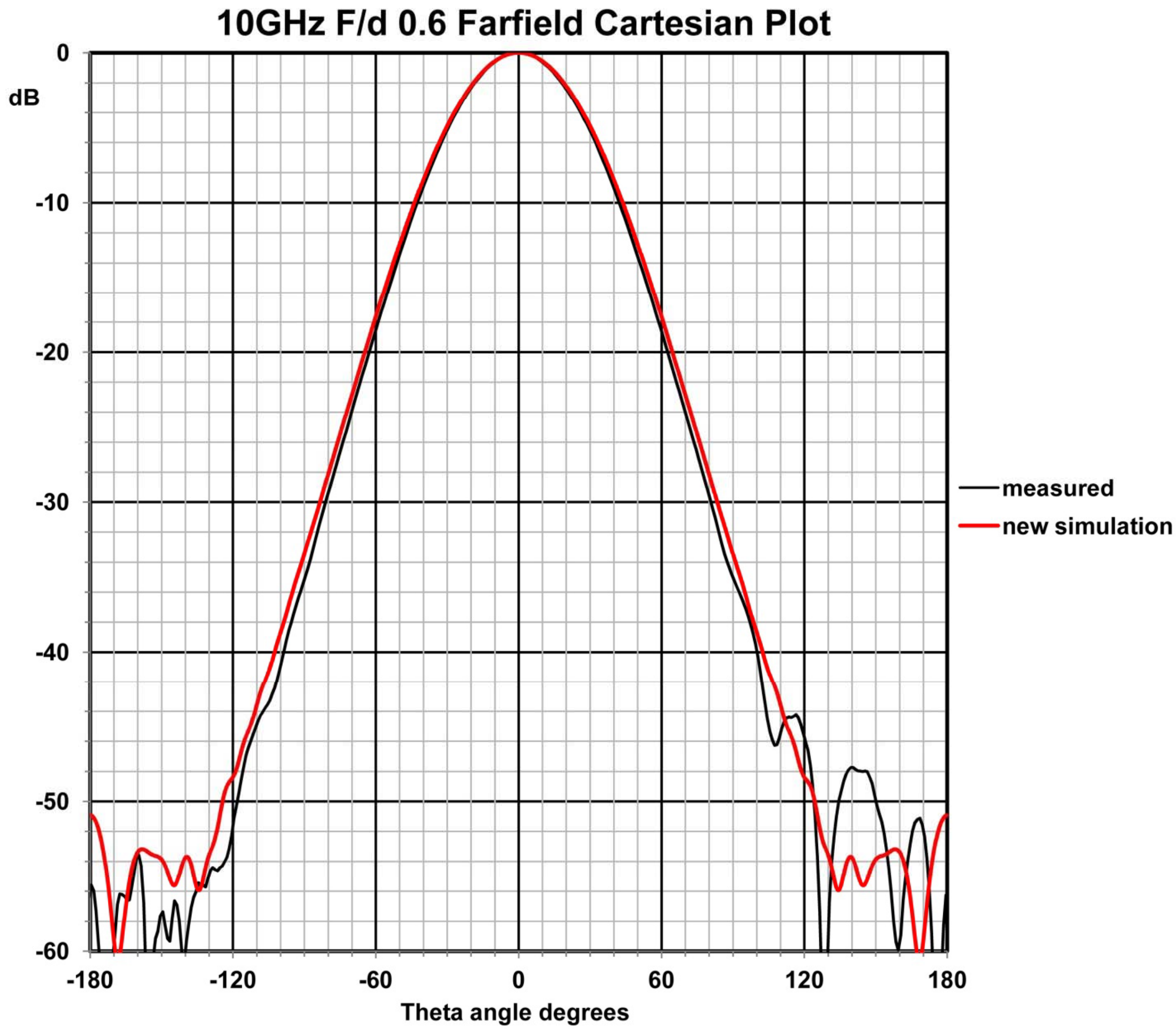

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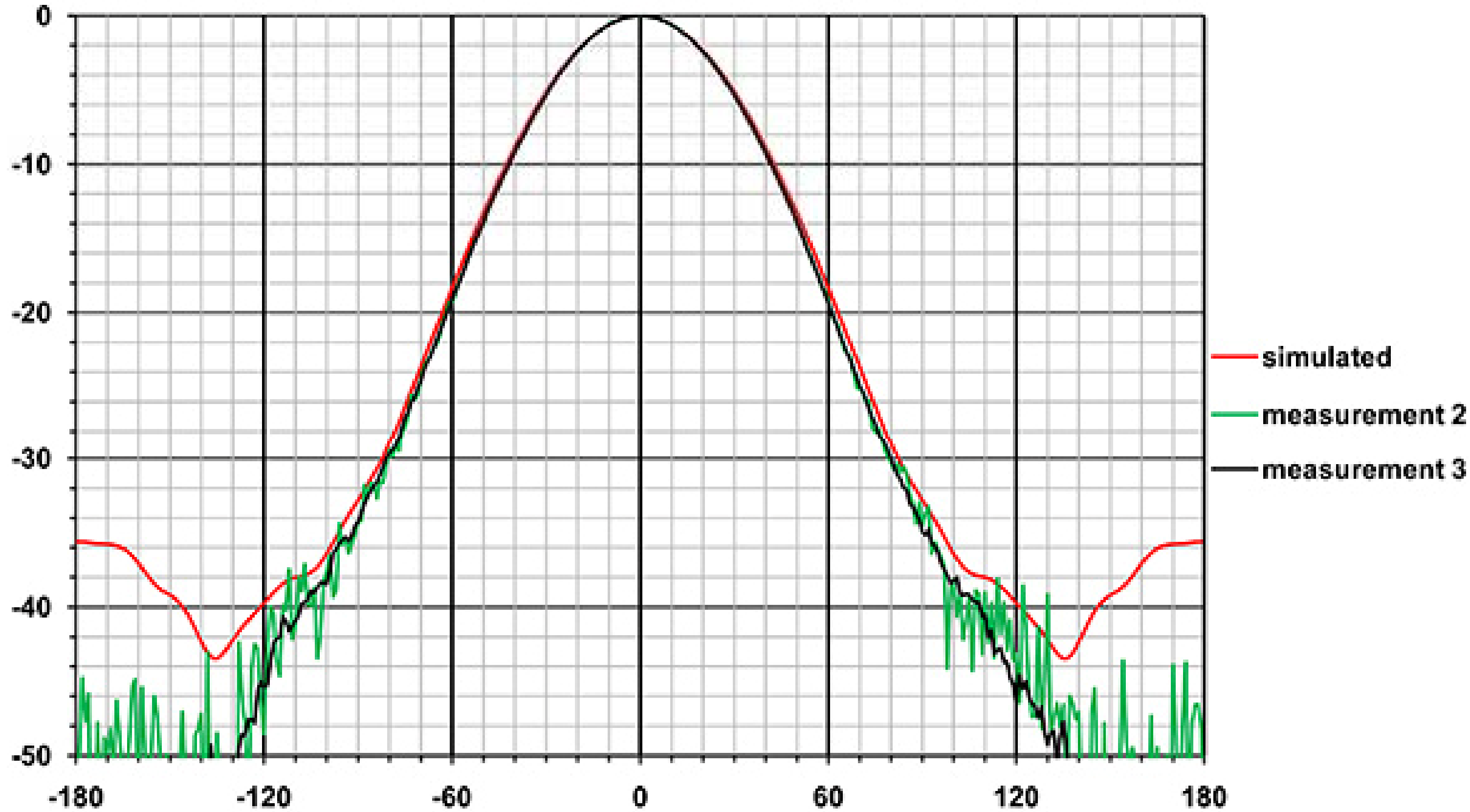

24GHz feed farfield pattern: compare CST simulation with two measurements

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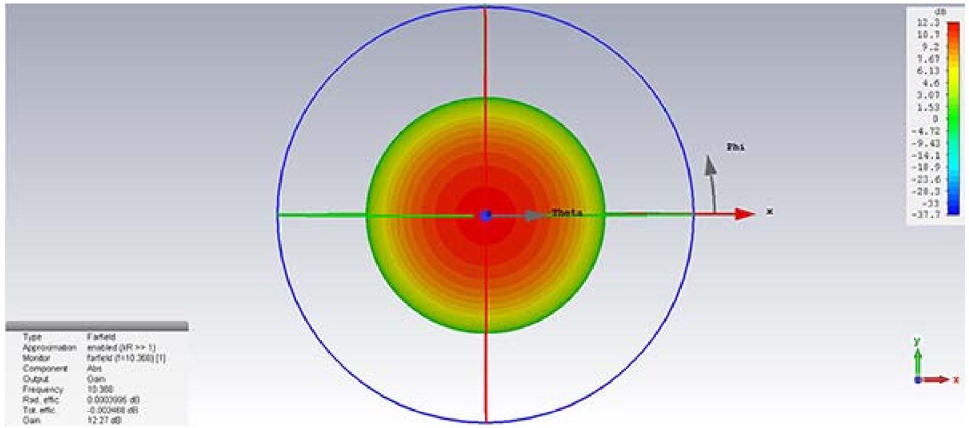

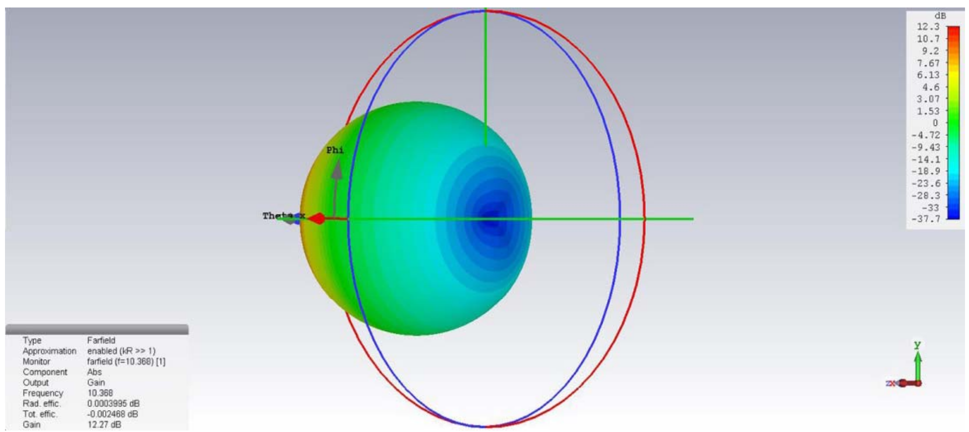

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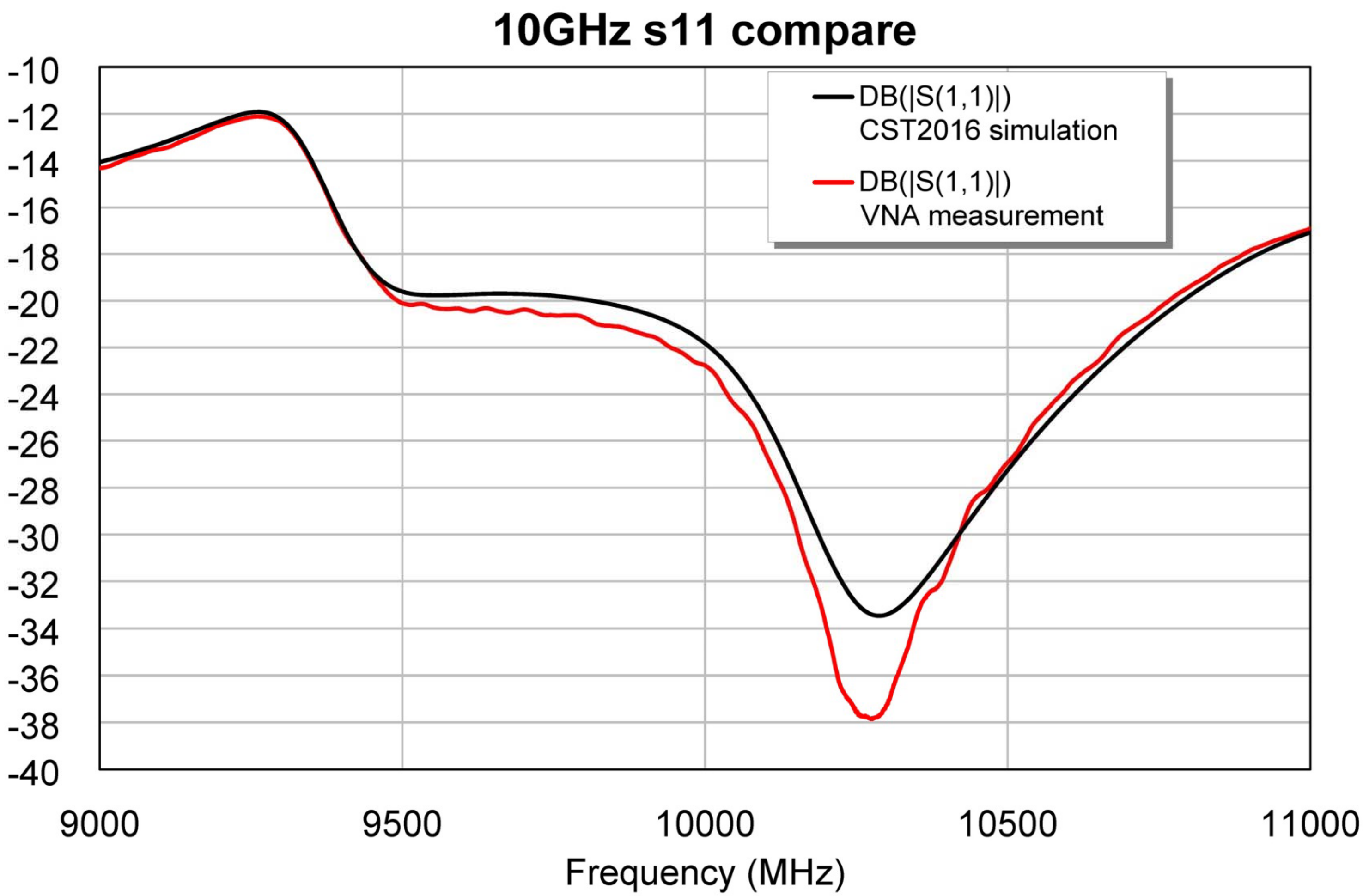
10GHz s11 compare
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
9000
9500
10000
10500
11000
Frequency (MHz)
DB(|S(1,1)|)
CST2016 simulation
DB(|S(1,1)|)
VNA measurement

Thanks to the material and interviews provided by Dan Bathker, JPL retired

A special thanks to CST of America who provided me with use of software that made this possible.

There are two Must Read books:
Samuel Silver, “Microwave Antenna Theory and Design”, first published in 1949 as volume 12 of the MIT Rad Lab series. Also reprinted by Peter Peregrinus Ltd, IEE London 1986 with Errata.

George Southworth, "Principles and Applications of Waveguide Transmission", in the Bell Telephone Laboratories Series published by D. Van Nostrand 1950, reprinted again in 1956 and 1959.

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