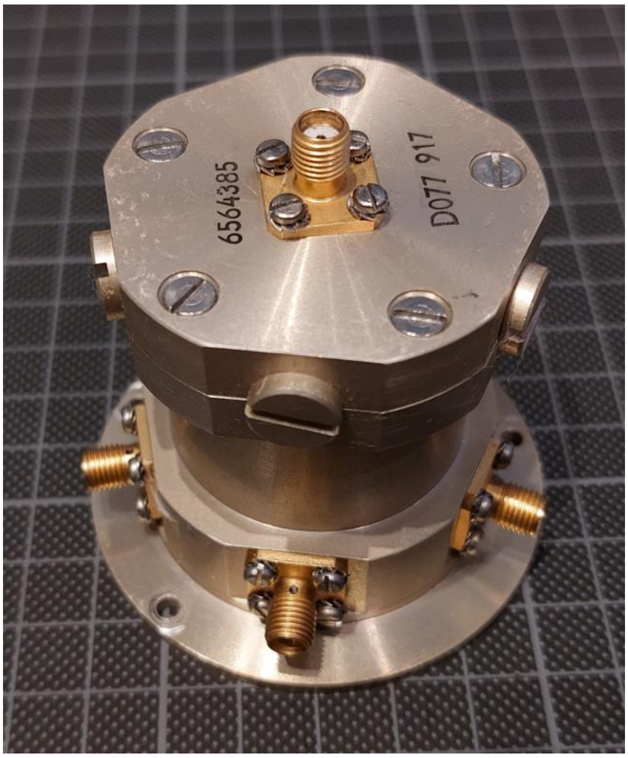
Analysis unknow L-Band 5-way power splitter & combiner

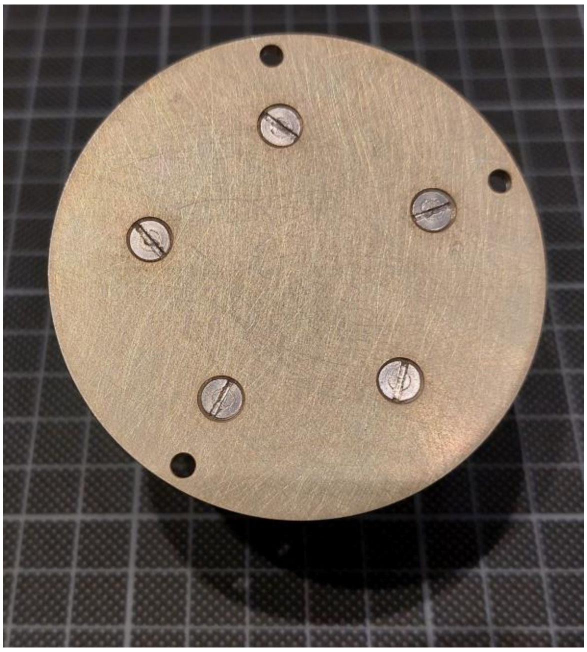
April 28th 2024, Matthias, DD1US, Rev 1.0

Hi,

Recently a friend gave an unknown RF unit. Based on its structure it looks like a 5-way power splitter/combiner but as there is no data available I and I finally found the time to analyze it.

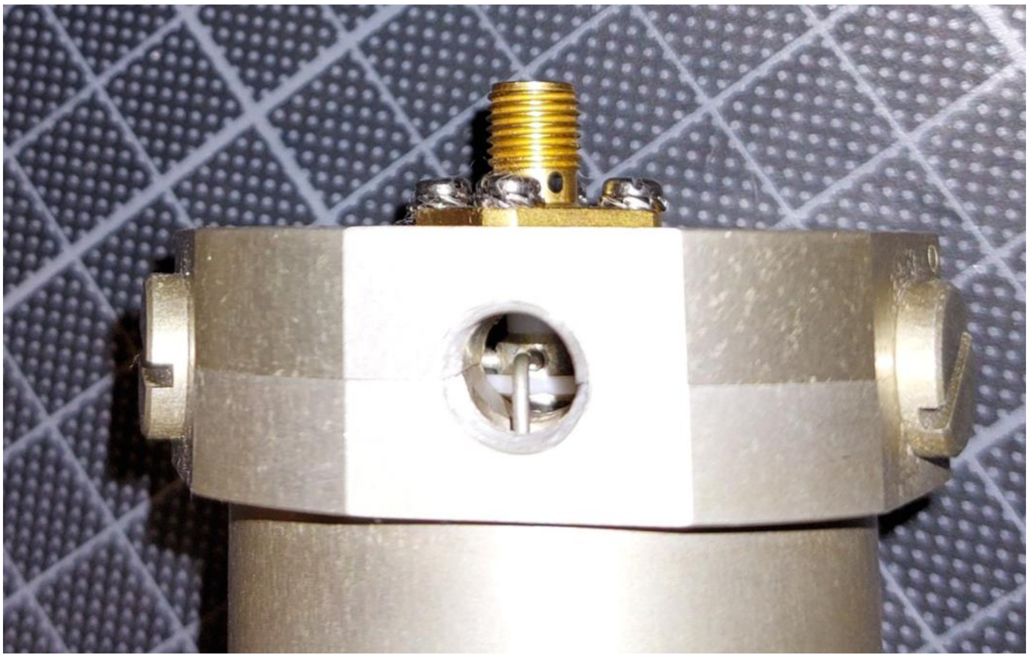
Here are some pictures of the device:





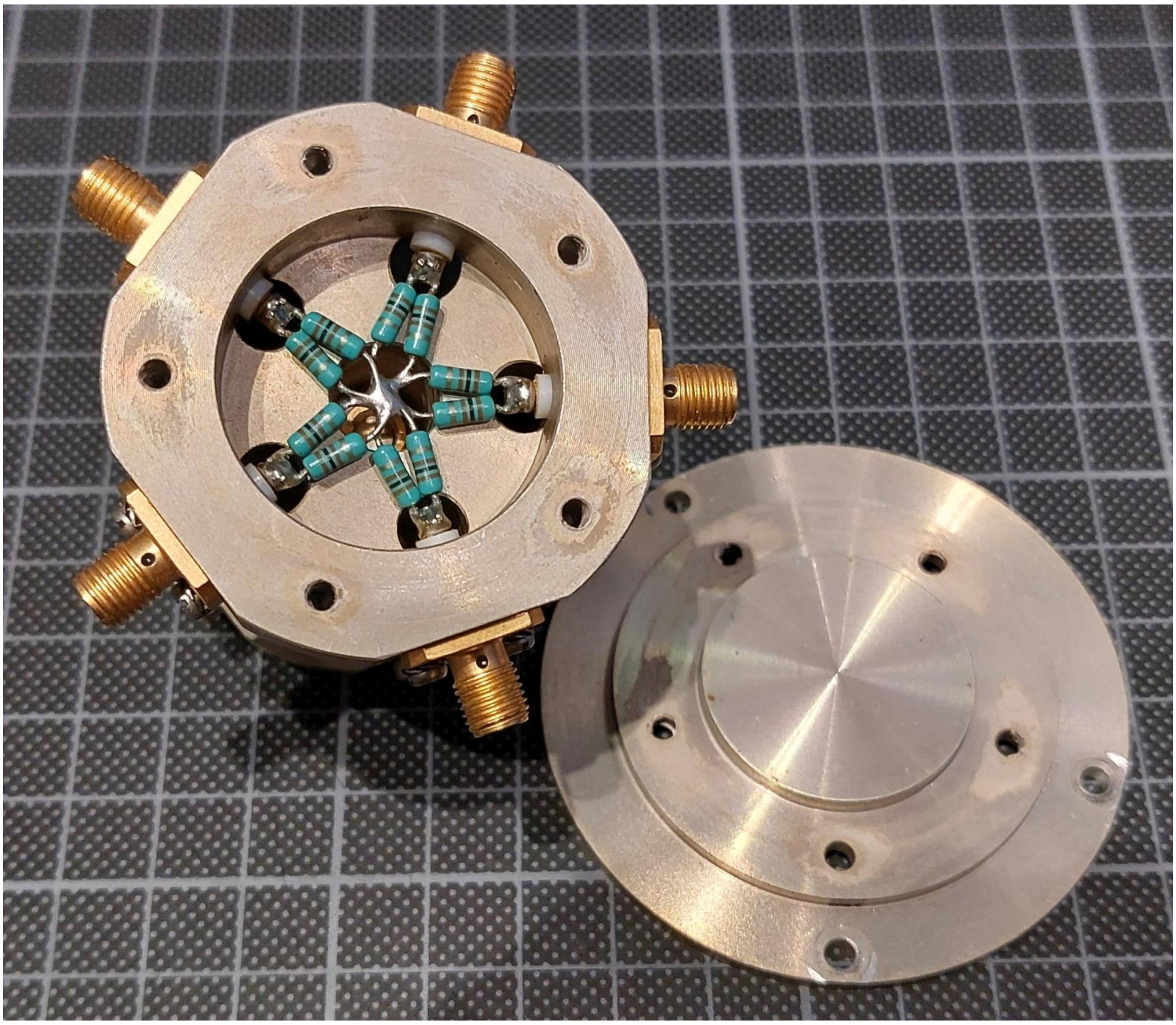
The only markings on the device are “6564385” and “DO77 917”. On top there is a central SMA jack and around the bottom of the unit are 5 SMA jacks equally spaced on the circumference.

I unscrewed one of the 5 covers close to the top and had a look inside:

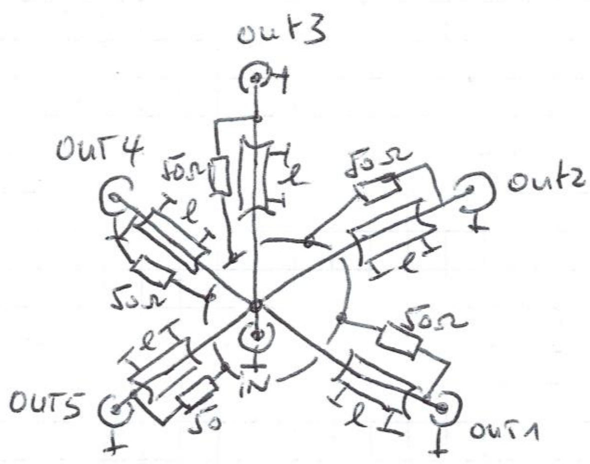


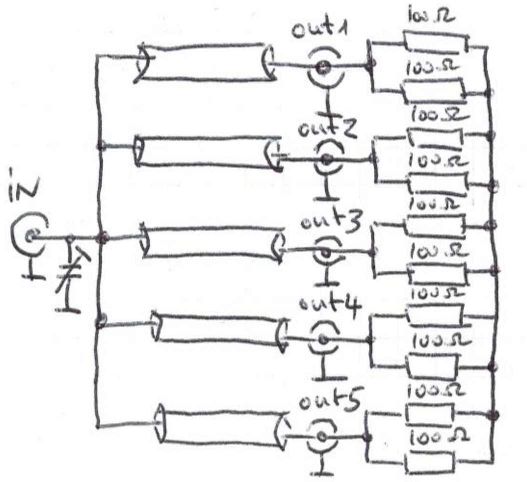
The unit is built very symmetrically and there are 5 connections to the top central SMA jack.

Next, I opened the bottom of the device:



The 5 coaxial lines coming down from the top of the unit are each directly connected to one of the 5 SMA jacks. In addition, from each of the 5 jacks two 100Ω resistors, which are connected in parallel resulting to 50Ω, are connected to a central isolated point. It looks like a “star”. I tried to make two sketches of the configuration:





The complete unit is built extremely symmetrically. The coaxial connections from the central top connector (I marked it as input in the sketches above assuming the unit is used as a splitter) to the output ports are exactly the same length. It can hardly be seen in the pictures above but there seems to be a tubular capacitor under the center point of the resistors connected from the center pin of the input SMA jack to ground for fine tuning.

Now we know: it is a 5-way splitter / combiner using the Wilkinson principle.

A nice description can be found at:

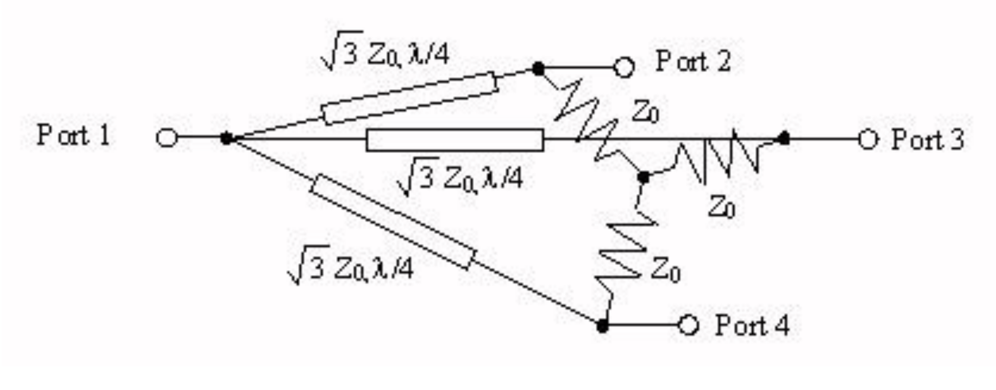
https://www.microwaves101.com/encyclopedias/n-way-wilkinson-splitters

Here is a short summary of the description on the microwaves101 website:

Radial N-way Wilkinson combiners / splitters are called that because they have radial symmetry. Above N=2, the splitter cannot be laid out in two dimensions.

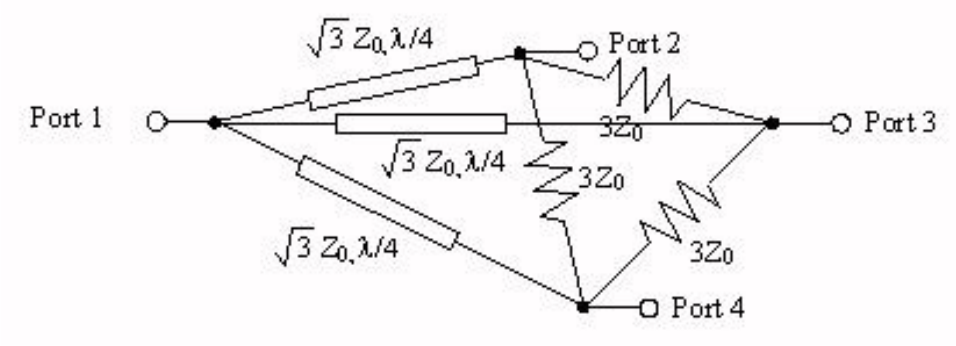
For N=3 split, there are two ways to realize the isolation resistors, the "star" and "delta" configurations.

A three-way Wilkinson is shown below, with "star-resistor" configuration. The arms have impedance SQRT(3) xZ_0, and the resistors have impedance Z_0.



(source: https://www.microwaves101.com/encyclopedias/n-way-wilkinson-splitters)

The next figure shows a three-way Wilkinson with the "delta" resistor configuration. The arms again have impedance SQRT(3) x Z_0, but now the resistors have impedance 3 x Z_0.



(source: https://www.microwaves101.com/encyclopedias/n-way-wilkinson-splitters)

Now that we've looked at the three-way Wilkinson, it is easy to guess what higher-order Wilkinson combiner resistor networks look like. We'll give you a hint... Every port has to be connected to every other port symmetrically. The "delta" resistor pattern gets really ugly, so stick with the star pattern for N=4 or higher.

For a basic N-way Wilkinson combiner, the arm impedance is SQRT(N) x Z_0. If you use star resistors, they are equal to Z_0. If you use delta resistors, they are equal to N x Z_0.

Well, and that is exactly the case with the unit we are analyzing here:

it is a 5-way (6 port) Wilkinson combiner / splitter in “star-resistor” configuration.

As it is designed for a 50Ω system (Z0=50Ω) all 5-star resistors are 50Ω (actually two 100Ω resistors connected in parallel to reduce the parasitic inductance and increase the power handling capabilities).

The impedance of the coaxial lines are SQRT(5) x Z_0 = 111.8Ω.

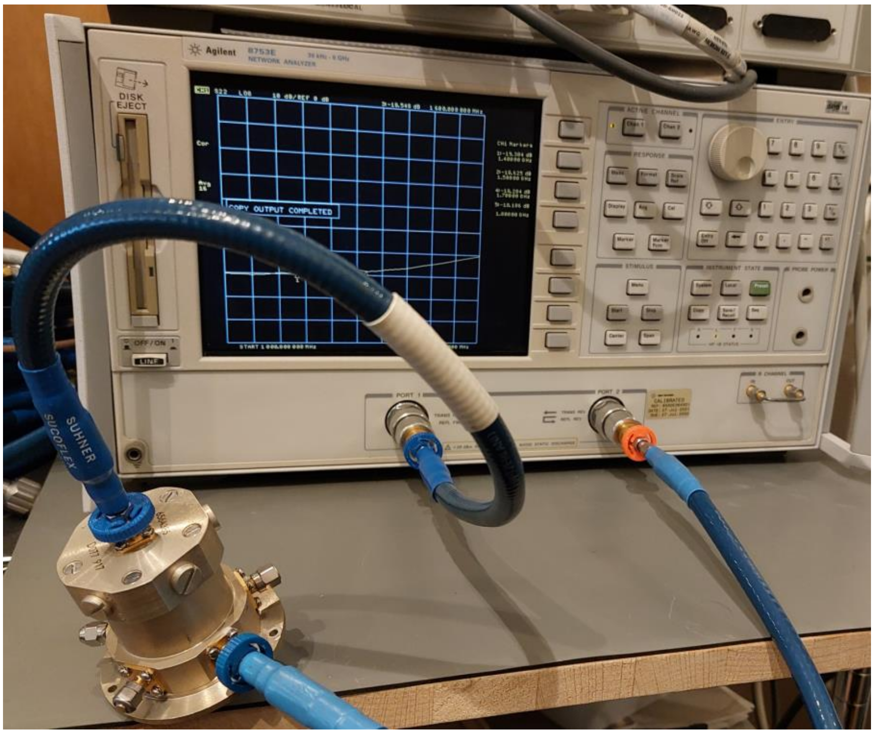
Their electrical length should be λ/4 and as the coaxial lines are using air as dielectric electrical and mechanical length should be very close. From the size of the unit, I estimated the design frequency to be about 1.5GHz.

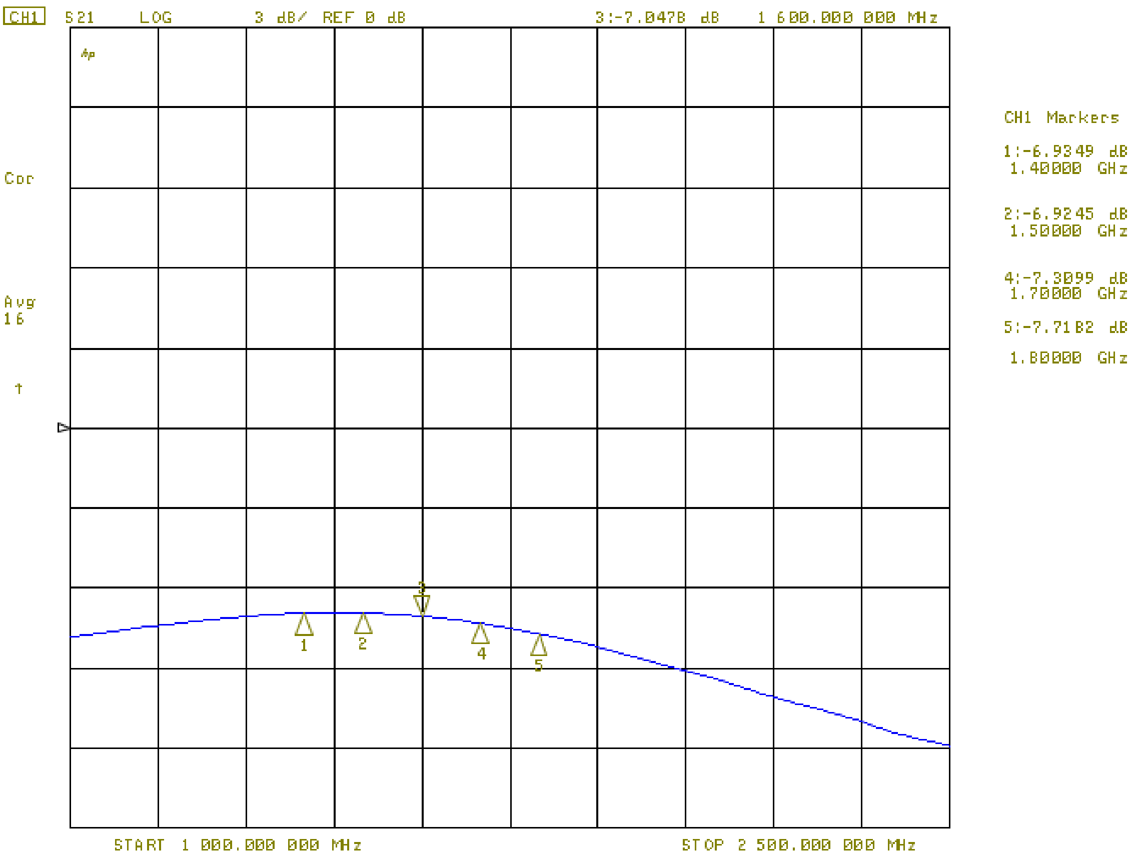
The theoretical insertion loss of a N-way splitter is calculated as follows:

Number of output ports	Insertion loss /dB
2	3.0
3	4.8
4	6.0
5	7.0
8	9

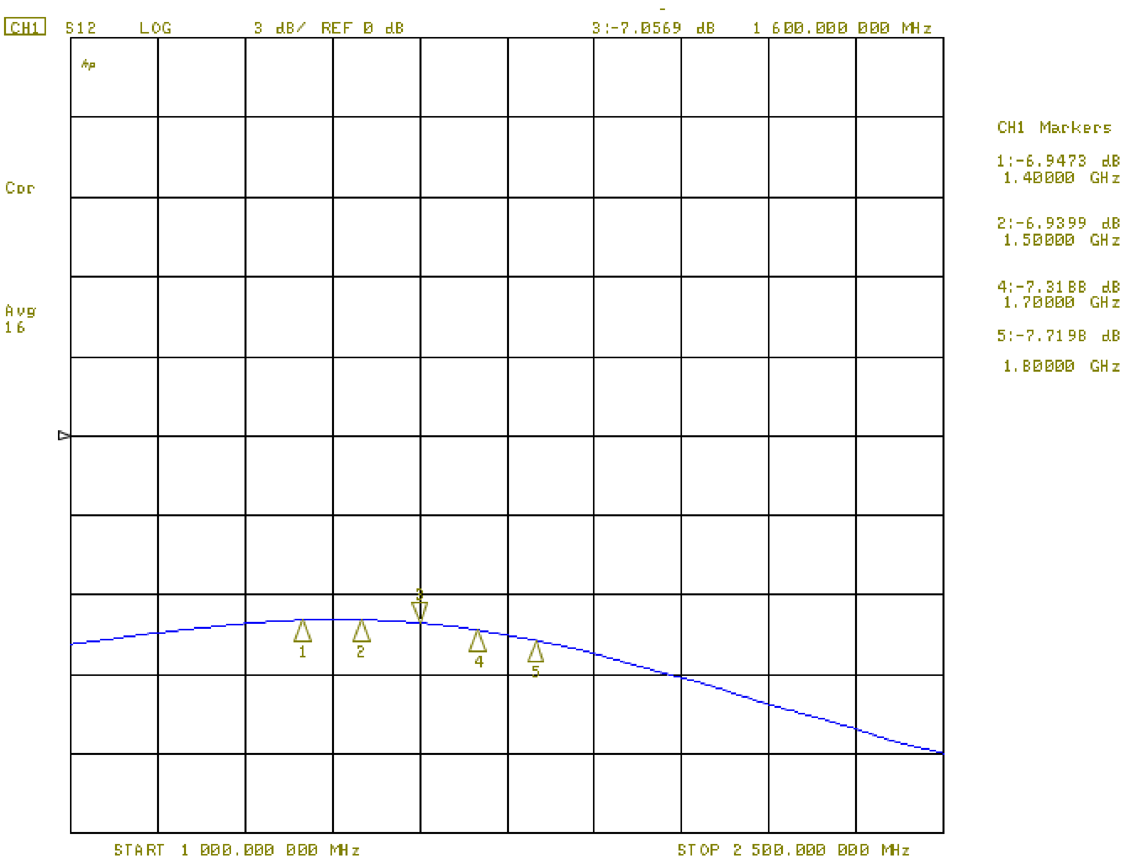
In our case we can expect an insertion loss of 7dB plus losses due to parasitic effects.

Next, I measured the device. I started with measuring the insertion loss S21 from the top center SMA jack (input) to one of the 5 radially arranged SMA jacks (outputs 1 to 5) in the frequency range 1 to 2.5GHz. All unused ports were terminated with 50Ω.

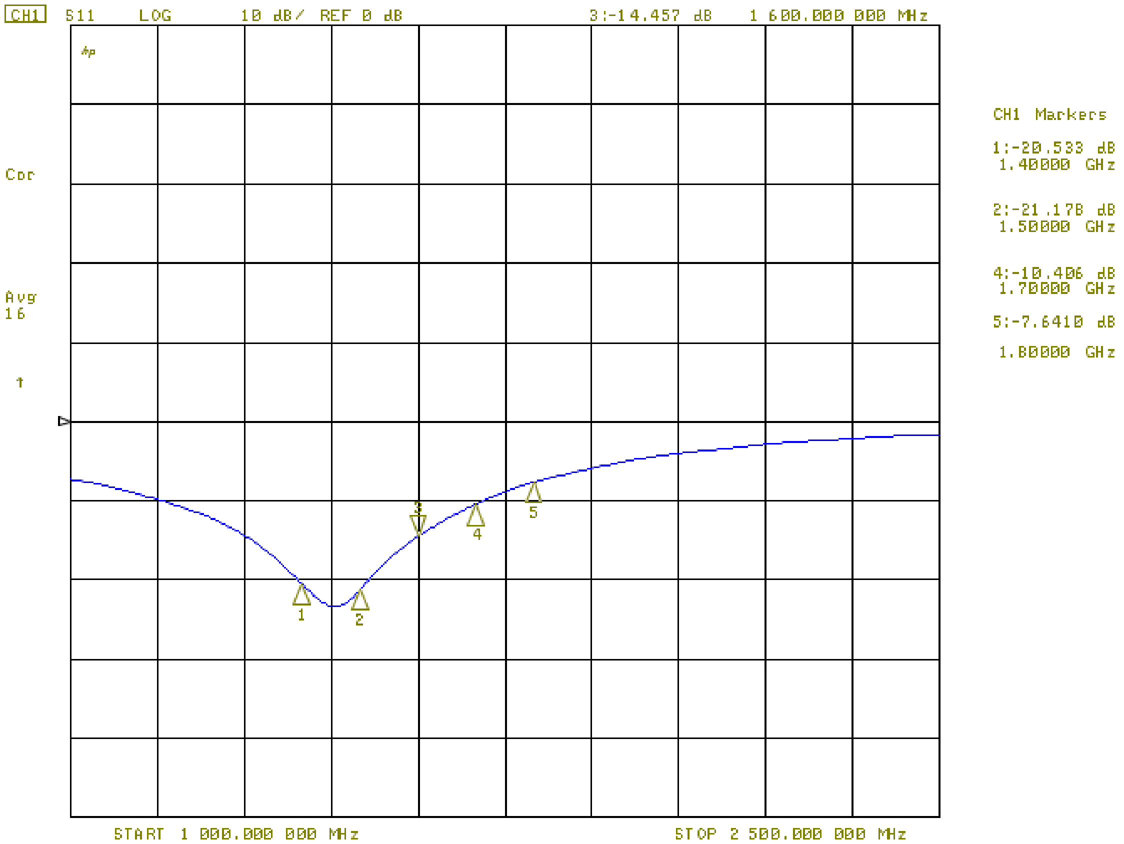




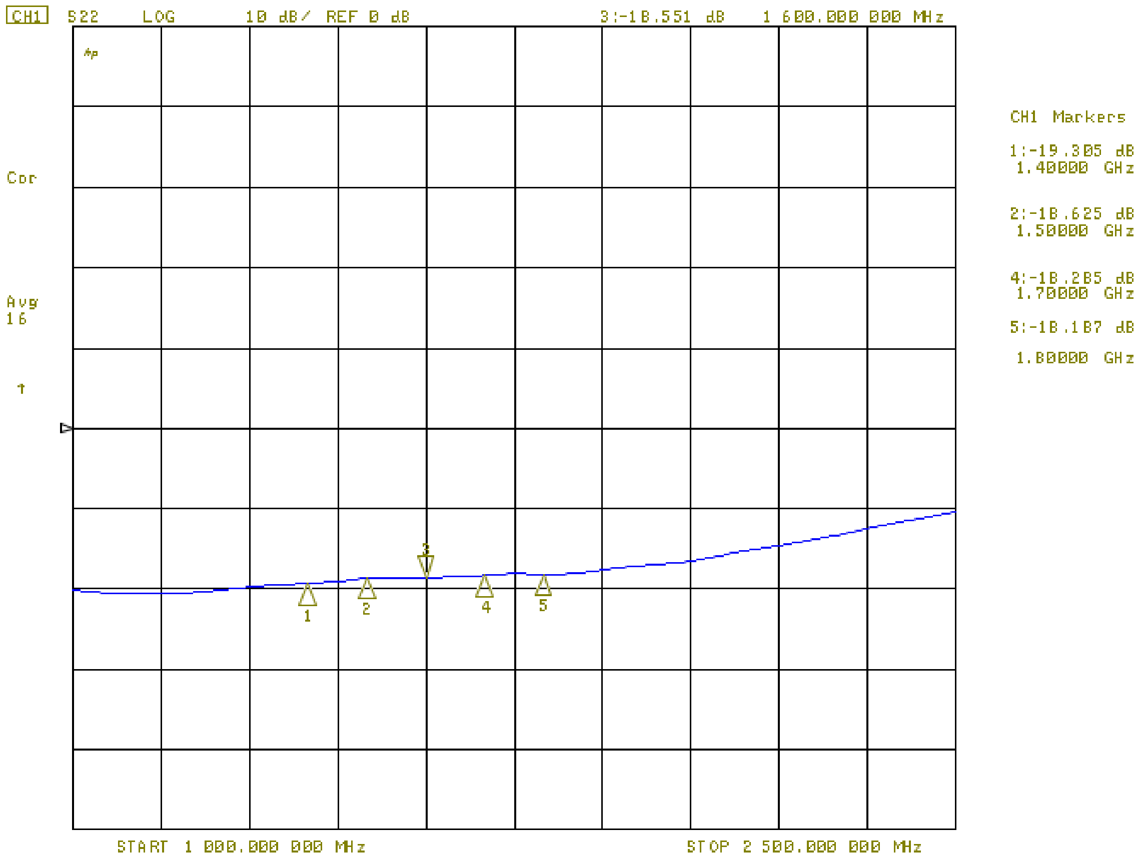
There is a broad minimum of the insertion loss of about 7dB in the frequency range 1.3GHz up to 1.6GHz.



Insertion loss in the reverse direction S12 shows an identical behaviour.

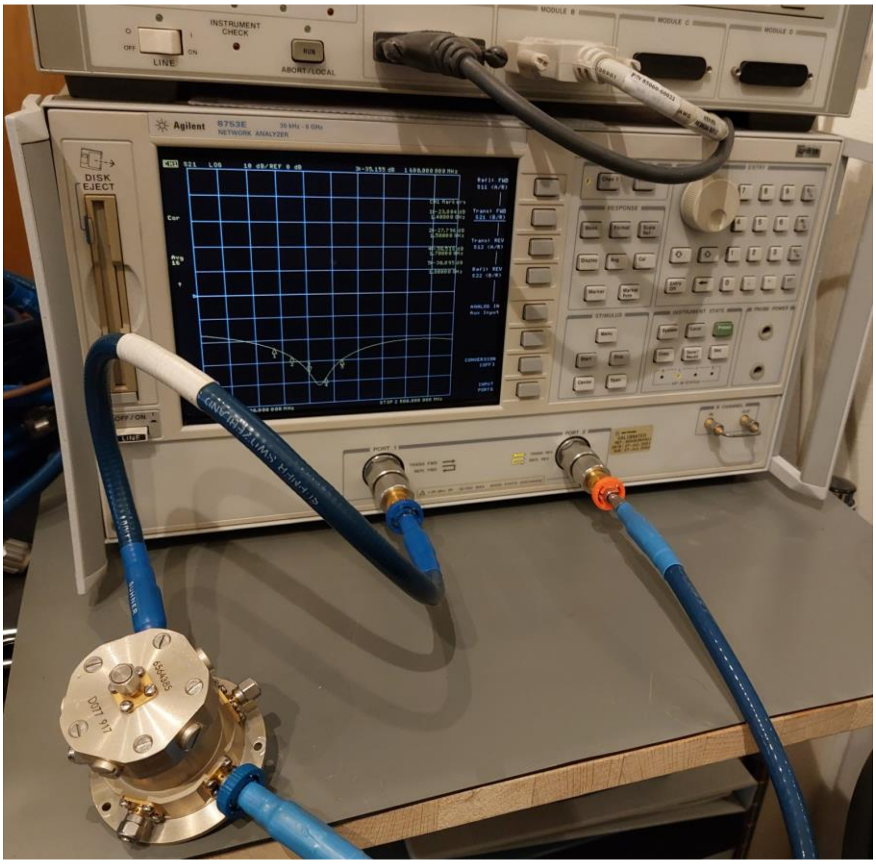


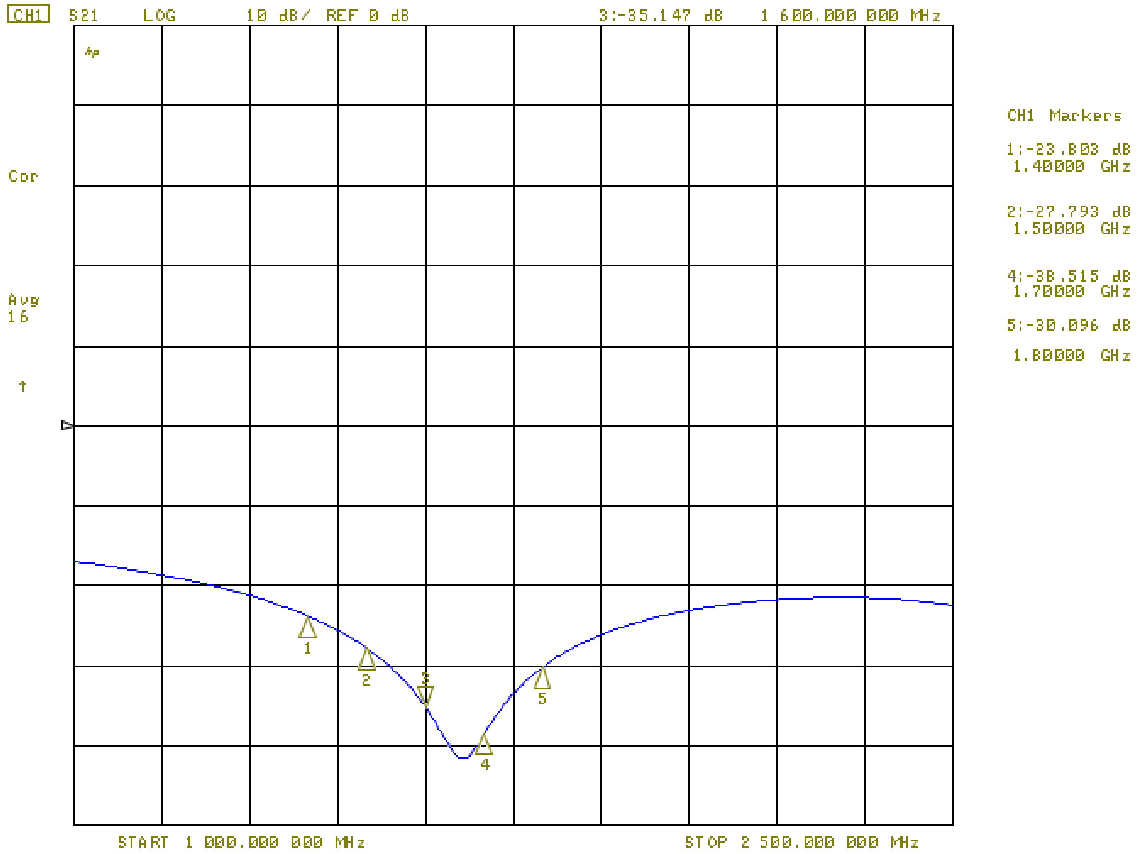
Input return loss S11 shows a maximum of about 23dB at 1450MHz.



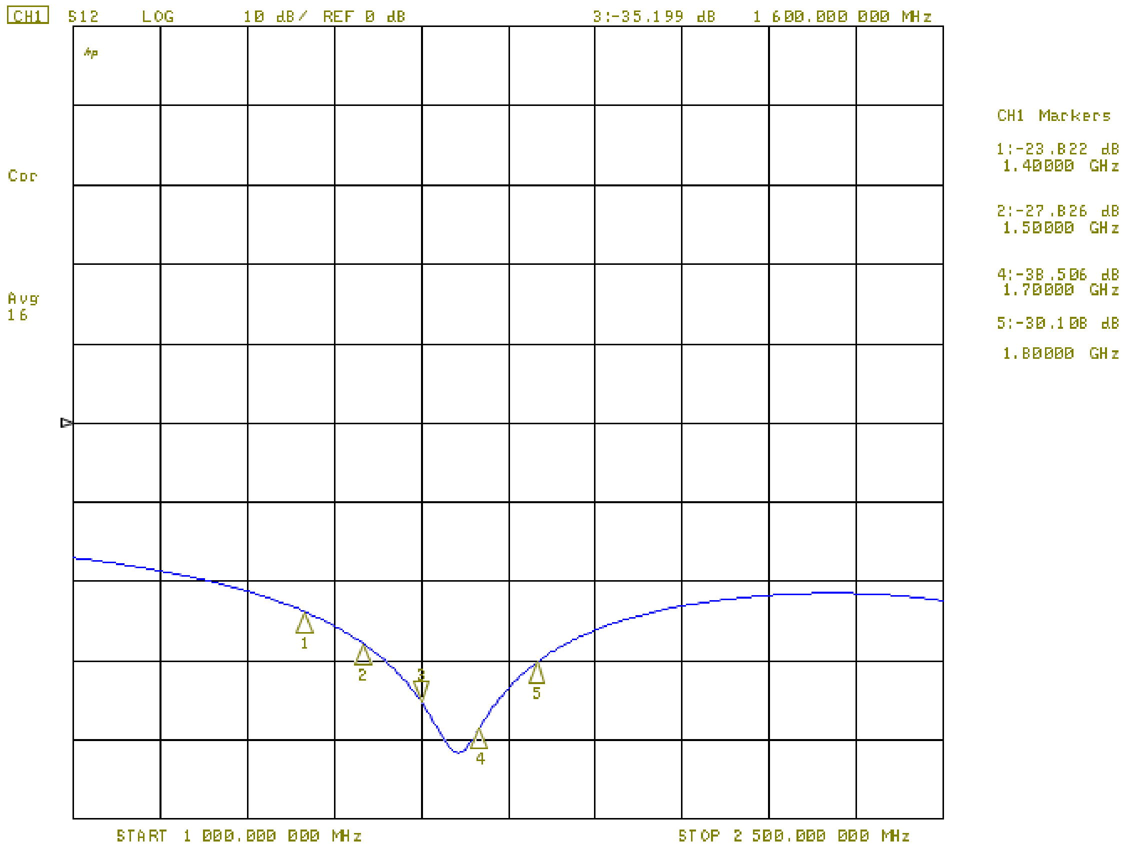
Output return loss S22 is very flat and about 18 to 20dB in the frequency range 1 to 1.8GHz.

Finally, I measured the path between two output ports. Again, all unused ports were terminated with 50Ω.

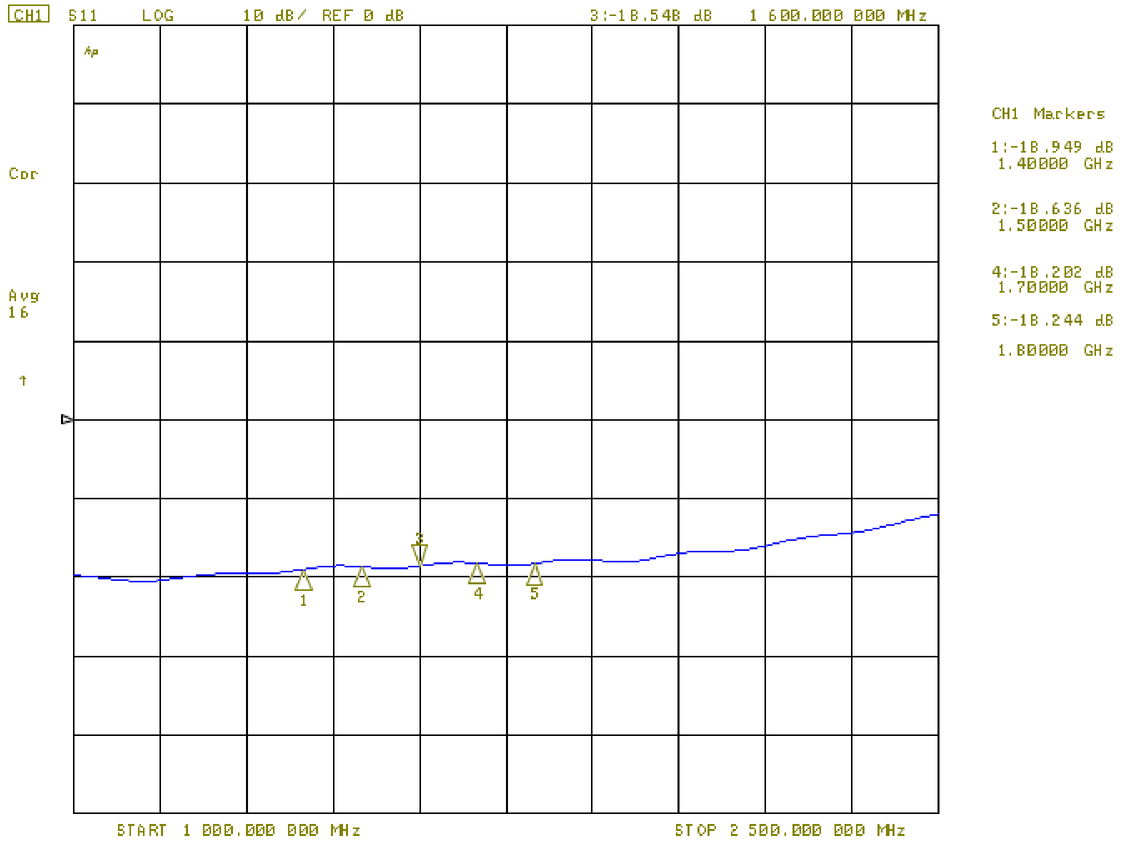


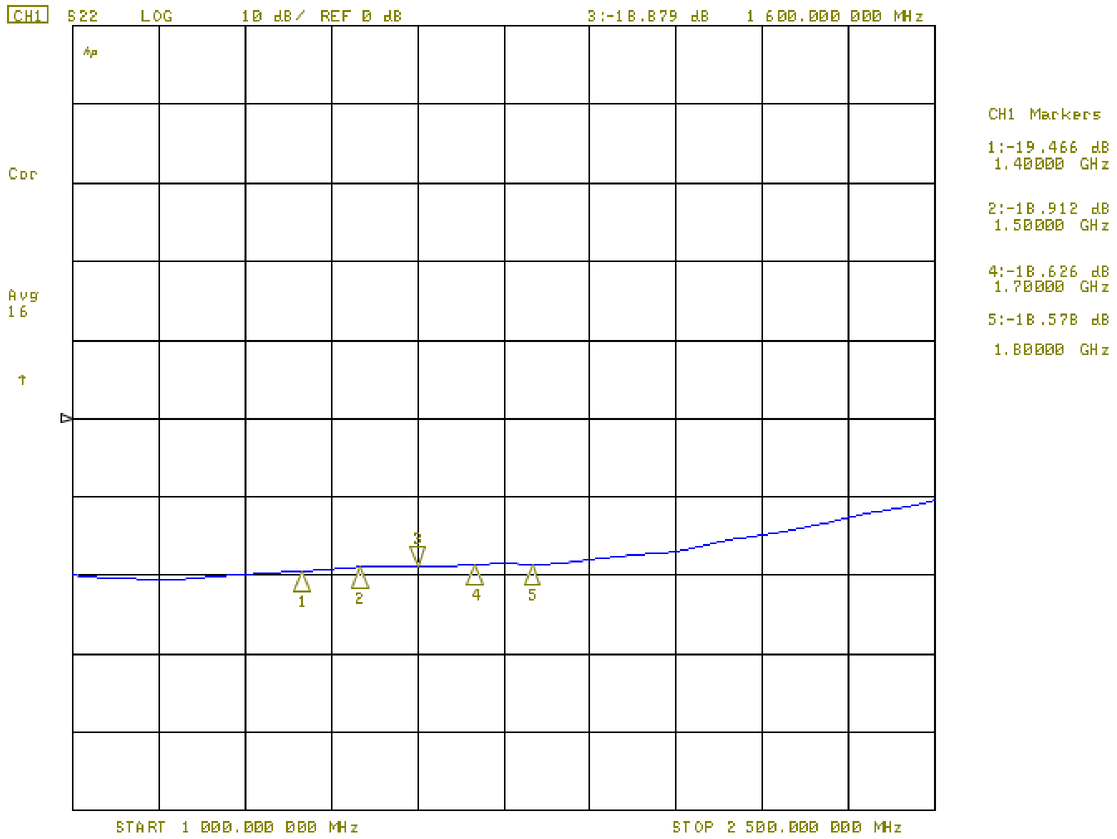


S21 shows a distinct maximum at 1680MHz with an isolation between the two ports of more than 40dB.



Insertion loss in the reverse direction S12 shows an identical behaviour.





As to be expected S11 and S22 show the same behaviour as been measured before. Output return loss S11 and S22 is very flat and about 18 to 20dB in the frequency range 1 to 1.8GHz.

In summary this seems to be 5-way power splitter/combiner targeted at the L-band downlink frequency band of HRPT weather satellites at about 1680MHz.

Performance is excellent with an insertion loss of about 7.3dB and thus only 0.3dB higher than theoretically possible and output port isolation of about 40dB.

If anyone has more information such as the source or even a datasheet with such a device, I appreciate any information. I will be also happy to answer any questions.

Please send it to my Email address below.

Kind regards

Matthias DD1US

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