# 5 GHz Synthesizer for
# High Speed DATA Link or ATV on 10 GHz and
# Spectrumanalyzer applications.

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The initial start-off for this project was the need for a 10 GHz link connecting Weinheim (DB0WPD) to Mannheim (LU), (DB0CPU). Nothing was available „off the shelf“ for TX at that time.
The prototype-link was running for some months in the end of 1999, but DB0CPU lost its QTH.
The prototype for ATV is running since 31.12.1999 as DB0UKW ATV repeater.

Since space in this script is limited to 10 pages, many of the pictures shown in the lecture are only availabe via INTERNET:
Follow the DB0WPD „DISH“ link at bottom of www.ukw-tagung.de

## 5GHz SYNTHESIZER

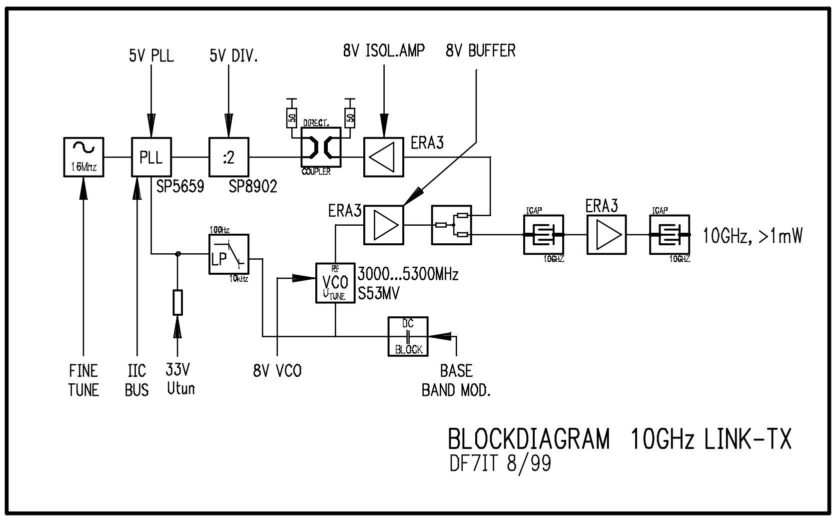
At the Weinheim 1998 meeting **S53MV** gave a lecture on Wide Band VCOs /1/.
He described a VCO running from 2.8 up to 4.6GHz.
I decided to try the design.
Instead of using 3 x 3.333GHz, use the first harmonic of 5GHz to get on 10GHz:
-More initial power on 10GHz.
-Less frequencies to filter.
Some 10 test circuit boards on 0.8mm FR4 EPOXY later, a 3.0GHz to 5.3GHz VCO was working fine.
S53MV uses his VCO as swept oscillator in his spectrum analyzer.
All commercial VCOs in that frequency range have only some 100Mhz to 1GHz range, (exept for YIG) and cost around DM 100.- (Micronetics, Z-Comm, Hittite as examples).
The idea of a compact, portable, battery powered spectrum analyzer from some 100kHz to 2.3GHz was born. The next steps leading to LINK_SYNthesiter had also this application in mind.
There are at least three issues related to the quality of a spec-analyzer main VCO:
(for general Block diagram of SA refer to last page of /1/):

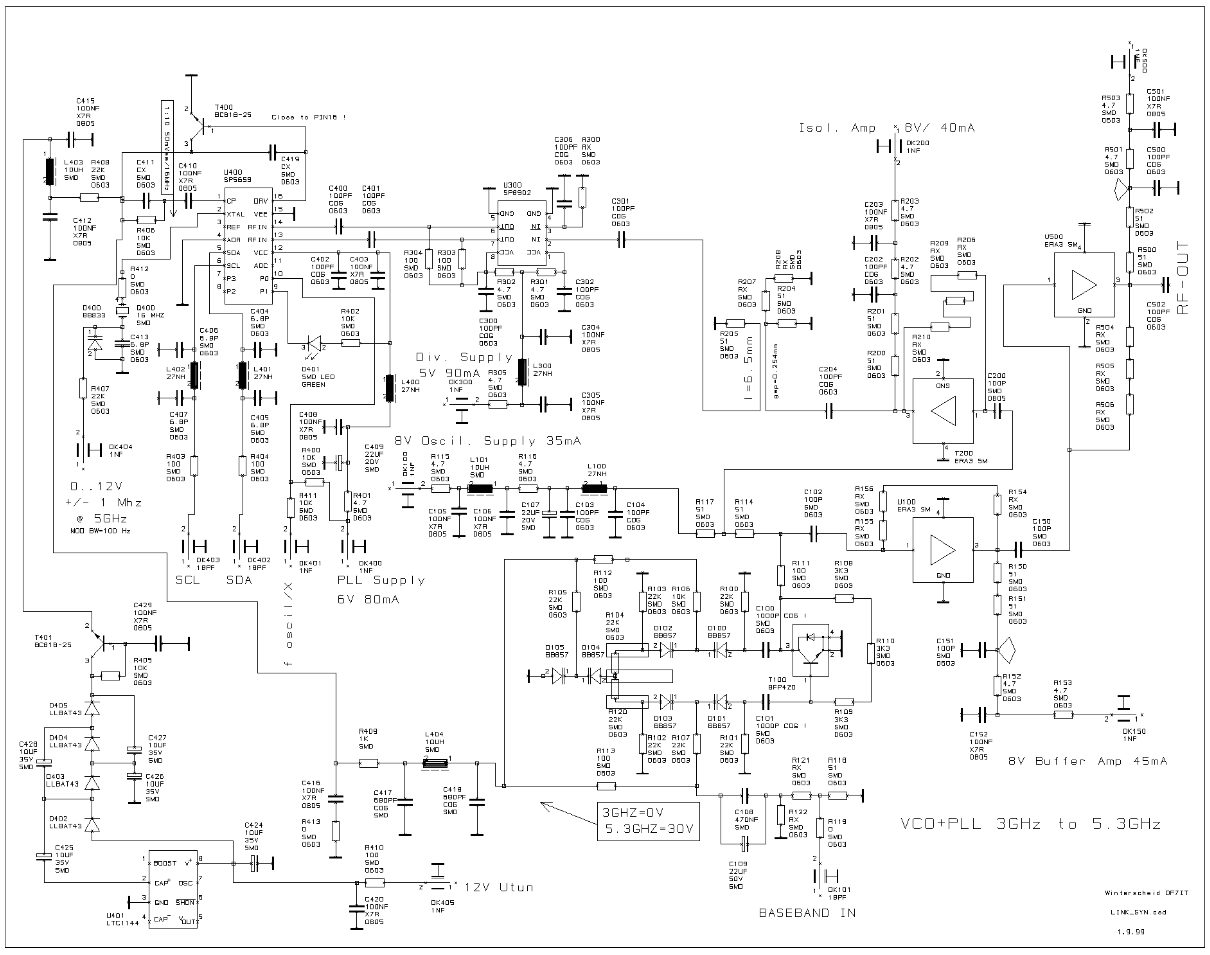
**1** -Only one frequency, no non-harmonic spurs (all n x fo will be generated in the mixer anyhow)
**2** -Phase noise performance (depending on minimum resolution-bandwidth)
**3** -More than 10dBm for high level mixer

Contrary to **S53MV**, i wanted a PLL stabilized/swept VCO, a synthesizer.
It is possible to lock a 5GHz VCO with a Mixer-PLL design, like DL1IN described in /3/.
But mixers do, what they are supposed to do: mixing.... many new frequencies are generated.
This does not meet quality **issue 1**: Only one frequency and its harmonics.
A „straight forward“ design needs a PLL which can handle 5 GHz. There is none to my knowlege.
So you need a 5 GHz prescaler.
I found one from Plessey (now MITEL): SP8902, in single quantity at about DM 75.-
But in order to keep fo/2 (generated by SP8902) away from the output i used an isolation amplifier with directional coupler to isolate the divider from the output.
The solution to **issue 2**: You have to filter all DC-supplies, and keep the tuning voltage line away from the REF-XTAL oscillator of the PLL.
As PLL i chose SP5659 from MITEL, also available as TSA5659 from PHILIPS (with minor differences).
With LINK&ATV application in mind, i chose 16MHz as REF-XTAL, so that sidebands caused by that XTAL are outside the used bandwidth. Comparison frequency was set to 50kHz. The SP5659 has a wider range of XTAL and comparison frequencies available than the popular TSA5055 or U6239.
You can also program the charge pump current. The price of abt. DM 20.- is also acceptable. SP5659 has a mode where the devided RF is switched to one output port (25kHz). This signal can be used to

check locking of PLL, or if not locked, the RF frequency can be calculated from programmed division ratios.
Achim, **DH2VA** built a compact handheld IIC-Bus programming box, so i didn´t have to run the computer all the time for programming the PLL.
**Issue 3:** use buffer amplifiers, in LO application bridge ICAPs with 100pF.

The scematic diagram of  LINK_SYN is shown  below.



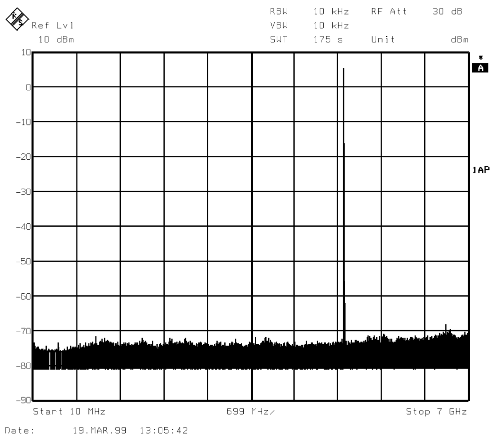



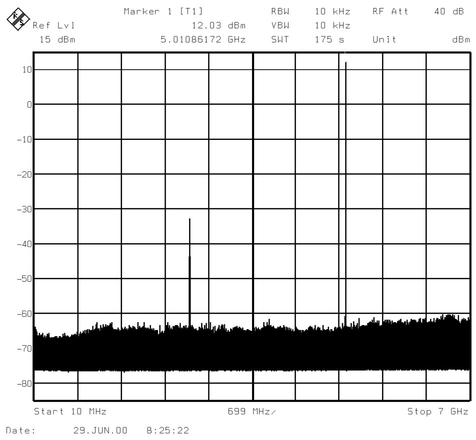
In short, from DC to 7GHz there is nothing but 5GHz for 80dB down.
Phase noise is about -90dBc @ 100kHz, Sidebands caused by 16MHz XTAL are also 80dB down.
(see spectrum plot below).
Nice for a Spectrum Analyzer swept LO, but too complicated, too many parts for LINK application.
(162 components, and thats only the RF-PCB!)

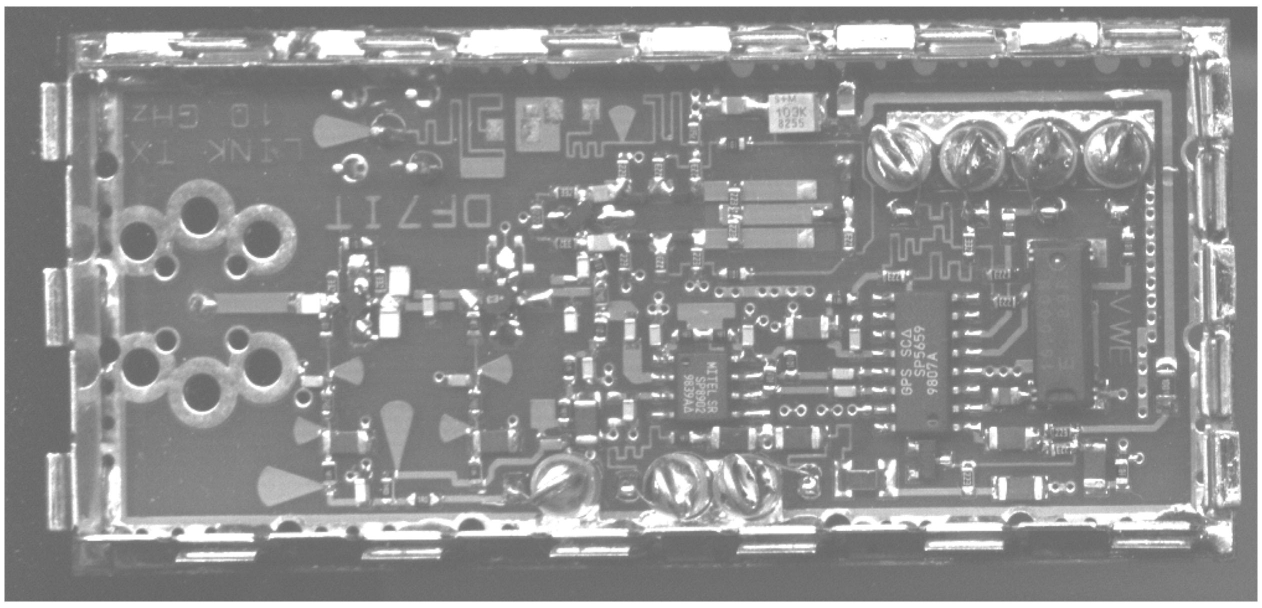
*The spectrum-analyzer project is still „on the drawing board“ and will we continued in the future.*
*Tests with BFP520 (fT=45GHz) as oscillator transistor resulted in up to 6.1GHz as max. frequency.*
*I hope to get some samples of BFP620 (fT=75GHz) very soon. But even BFP520 are hard to get in the moment (>40 weeks).*

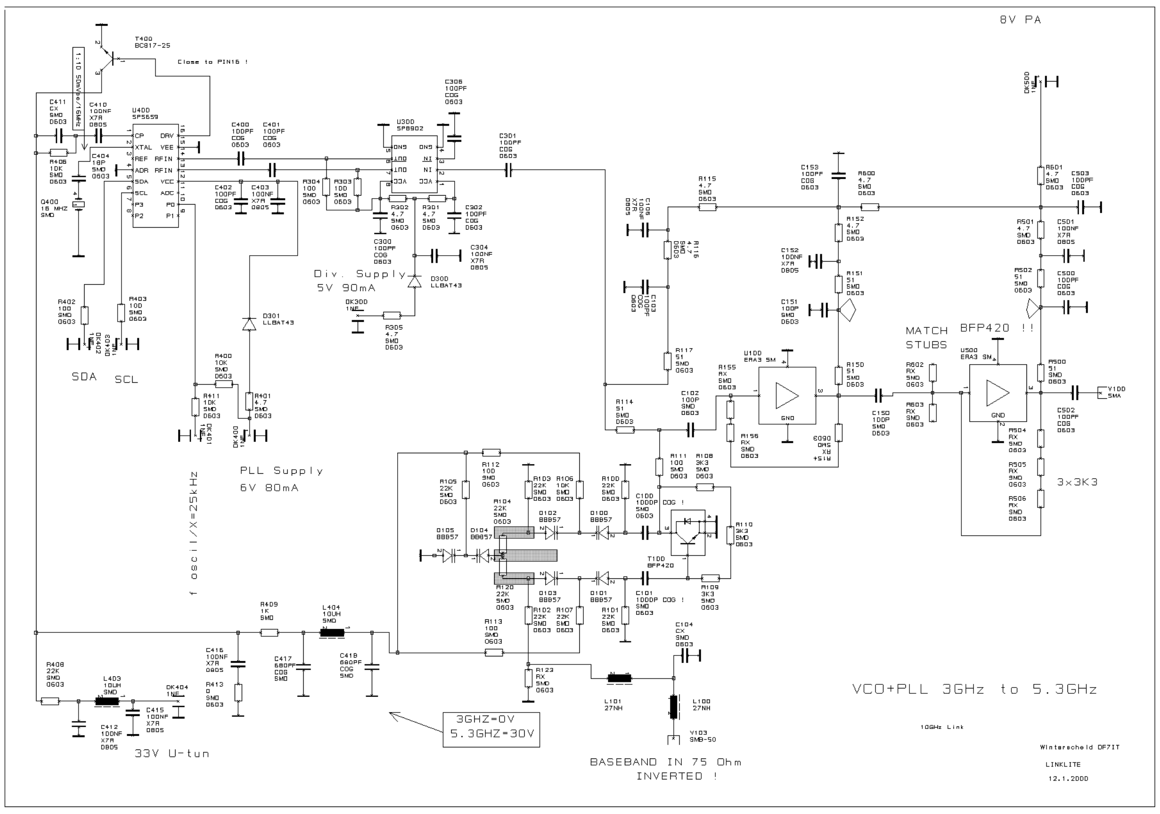
## LINK-LITE

The name says it all: Many components where thrown out (now only 121 left):
In the PLL RF feedback the Buffer Amp ERA3 and coupler were removed.
The result is the degradation of isolation of f/2 to the output.
Some DC filtering components were removed.
Varicap tuning for REF-XTAL was removed.
Components were moved closer together. LINK_SYN used 108x35mm, LINKLITE only 82x35mm.
The spectrum of both synthesizers at 5GHz is shown below.

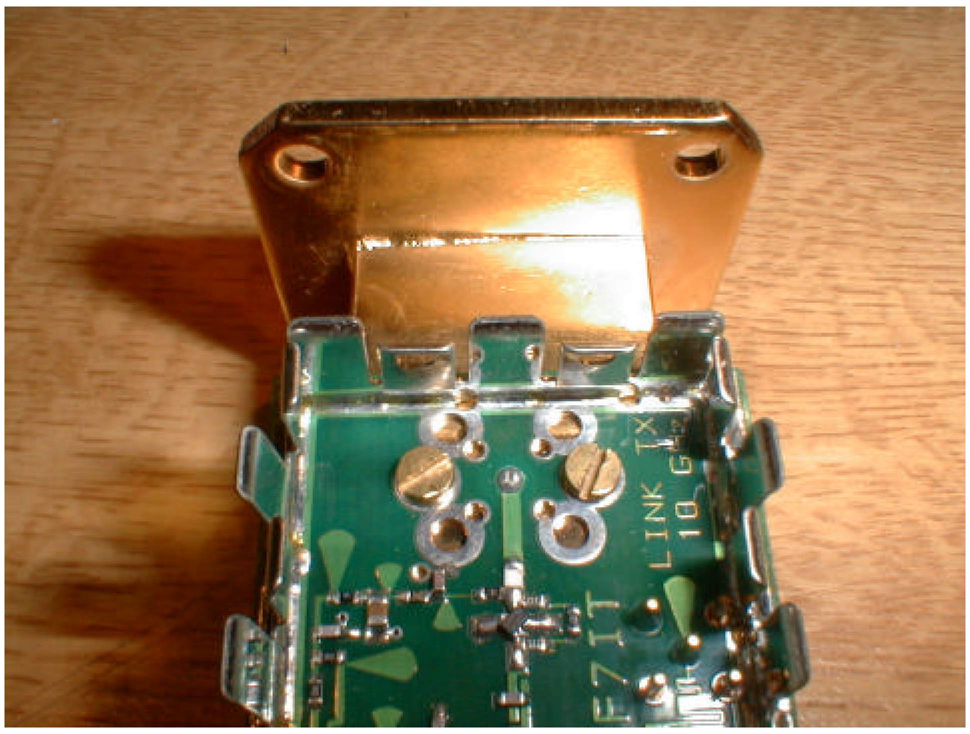





A lot of 0603 components. The varicaps BB857 are only 1.2mm x 0.7mm.
**This is no SMD-beginners-project !**
At the output, drill holes for SMA flange as well as for SMA Plugs were put onto the layout.
Soldering a  7mm PIN to the output, and connecting the PCB with 2 screws to a lenght of R100 waveguide as highpass filter  a Power Meter showed roughly 5mW at 10 GHz (or better: above 7GHz).
Two matching stubs (2x 0 Ohm 0805, upside down) at the base of the last BFP420  (just beneath the „7“ of DF7IT (picture on previous page) increased power to 8mW (typ:10mW).
This was the same for all  PCBs i built(about 20), so that the stubs are included in the new layout.
Later on, a test at the FH-Mannheim RF & OPTO Lab. revealed that 15GHz is at  –18dBm.
20GHz could not be detected and even their spec-analyzer stops at 21GHz.
Somewhere FR4 EPOXY has to take its toll.



For easier testing, the TX block was split into two boards: LINKLITE and PIC
For details see WEB Page mentioned above.
**PIC** does the following:
Programming PLL SP5659:

On power up: Read 5 Bit jumper for desired frequency (32 Channels)
Switch on Power for PLL/Oscillator/Amplifier
Programm PLL

Operation Loop: Check RF/x (=25kHz if locked)
If not OK : new power up sequence

Test Mode: Synthesizers sweeps around center frequency (for filter tuning, etc..)

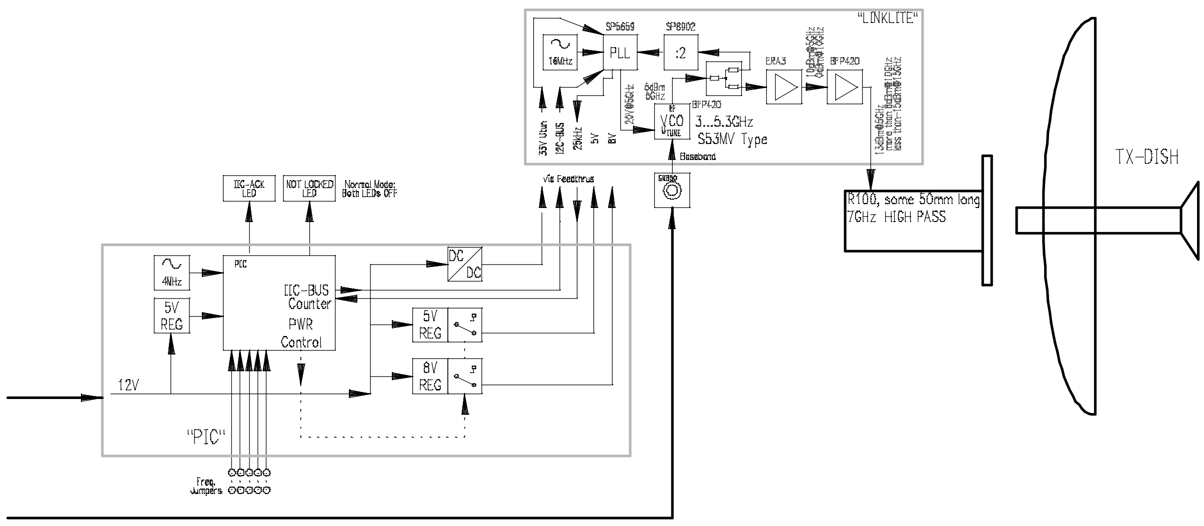
All the needed supply voltages (5V,8V,33V) are derrived from 12V.
(PIC program by **DH2VA**)
In the early version we programmed the PLL from the shack. Also the devided RF was fed to the shack. But at DB0CPU the PLL IC could not cope with the long line. (more than 10m). Also random power-surges reprogrammed the PLL to some (random) frequency.
Now, with the PIC directly at the TX, this is no longer a problem.

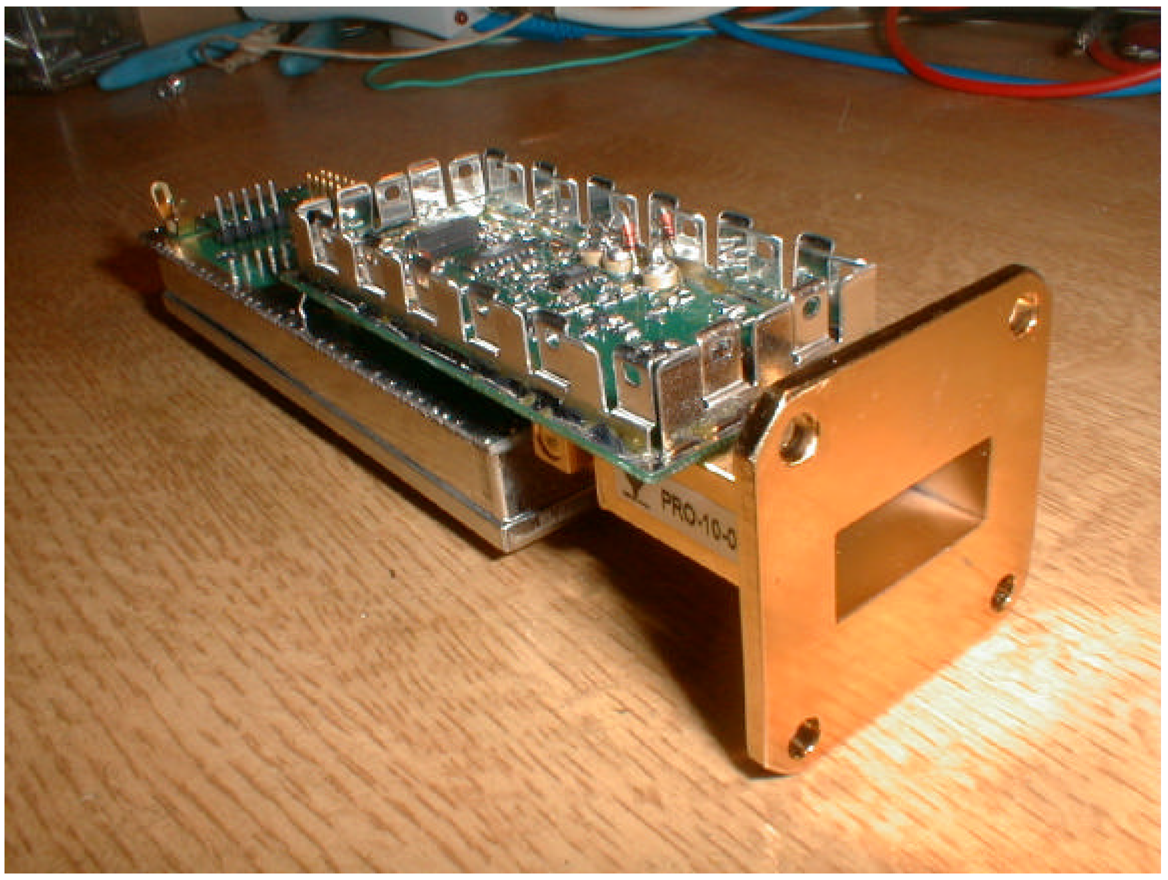
Monitoring the LINKLITE is possible from the shack via supply current:
some 220mA is normal, if it is much less, there is a problem.
If something is wrong, the currents pulses with abt. 1 Hz. (PIC switching power on/off)

This PCB is actually bigger than the RF-PCB. But the whole block „fits“ behind the shape of a R100 flange. Also there are no 0603 or smaller SMD...
For the transmitter there are now only 2 connections to be made:
12V and Modulation-Baseband coax.

In Link application (with 3 MHz Modulator, see below) it should be possible to feed all signals thru one COAX if necessary (test not yet completed):
DC Power for TX and LNC
3MHz TX baseband
1.xGHz receive signal from LNC.

**Block Diagram of TX "FRONTEND":**






## Modulation

LINKLITE is modulated from the GND Side of one of the 6 Varicaps.
There are some advantages over the usual way of coupling the modulation onto the tuningvoltage via a large capacitor:

1. If you feed the modulation over longer cables, you have a load of 75 (50) Ohms. Good „VSWR“ is a problem, even at 5MHz.
   (We tried otherwise over 10meters lengh and failed and had no idea why for a long time ...now we use 75 Ohm TV coax to feed baseband to the TX).
2. No need for coupling capacitor, even though DC is not possible due to PLL.
3. You have free choice in LOOP Filter components and values.

.....but there is a „but !“ ...

Modulation polarity is inverted, that means that you can´t use a video signal directly to modulate (some SAT-Receivers can be set to reverse though). In Link application, this does not matter.

It was possible to design the LOOP Filter slow enough so that Video Modulation is possible without degrading stability of PLL lock. Most Base-Band-Processors like the one from DK2DB have inverter function. This configuration was running as TX (with 200mW Amp) at DB0UKW ATV repeater as beacon starting 31.12.1999. Hopefully the repeater is on the air with full repeater function by now.
There might be a problem with tilt on the video signal. I first thougt that it is a problem of PLL but without PLL and fixed tuningvoltage, the problem persits and seems not to change with component values around the oscillator. But some SAT-Receivers don´t have the problem as much as others.
Maybe it is a problem with my scope.
For the link to DB0CPU we used RMNC Cards with 38k4.
The modulation signal has DC components, which were promptly compensated by the PLL (even with slow ATV loopfilter).

Manchester Encoding would remove this „DC“ problem /2/, but we opted not to change anything on the RMNC side and built a subcarrier modulator instead.
This makes it easier to just change Links from 23cm to 10GHz for path testing. For higher speed, nothing has to be changed at the antenna. A 3MHz VCO is linearily shiftet: LOW=2MHz, HiGH=4MHz and all inbetween. With this, modulation down to DC and up to several 100kHz is possible. Eye pattern stays the same. Also it is possible to feed baseband and DC-supply thru only one coax.

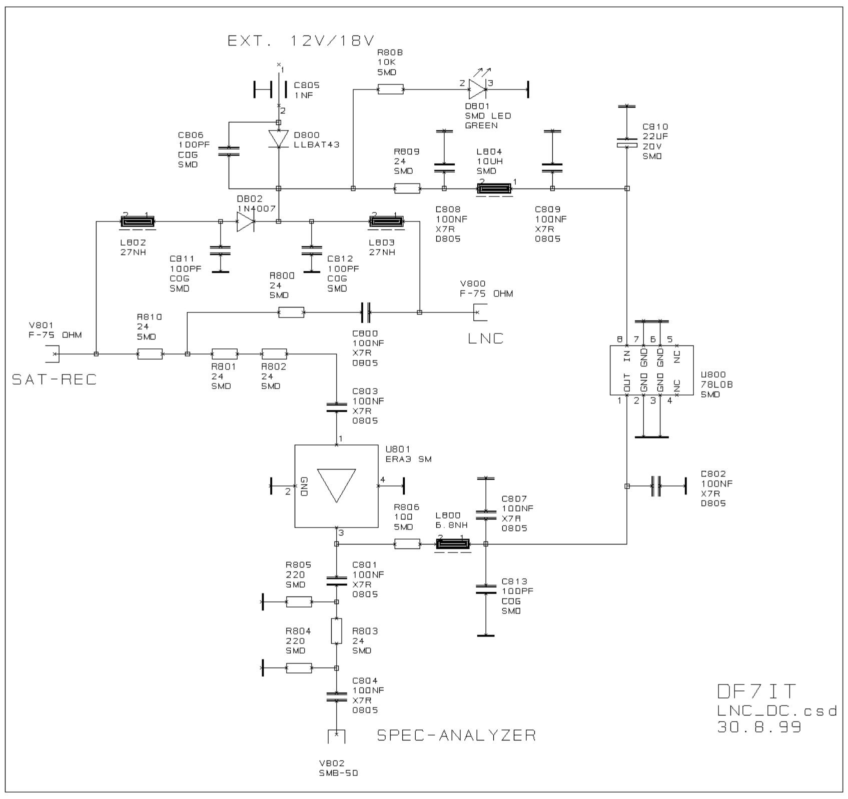
## Receiver

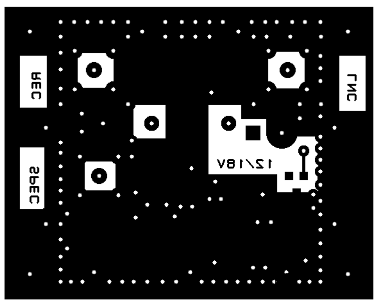
Several descriptions of 10GHz Links where published, as examples:

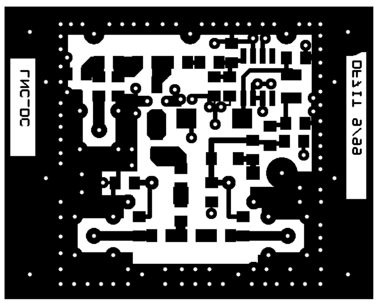
Link project : www.qsl.net/KE5FX, DF5TY (/2/), ARRL Handbook

11Ghz Astra dishes with LNC plus Receiver are availabe in Germany for as little as DM 99.- or less.
Just replace the LNC with one modified for ATV (abt. DM 130.-), or modify the one supplied with the dish.
The modified LNCs have LO at 9GHz, which means that a link frequency of 10.25Ghz is converted to 1250MHz on the 75 Ohm LNC coax.
If you want to test your system with modified LNC, a good beacon ist available: ASTRA
ASTRA band starts at 10.7GHz, so the first 10 channels will be inside receiver frequency range (1700...21xx MHz).Adjustment of Dish focus is easy, since there are no ground effects!
If you see a noise free picture, the system noise figure should not be too bad.
You also can check if the frequency display of your receiver is set to the right "LO" frequency.
If not, you will have 250MHz offset. (This almost killed our first "field-test").
With three variables: frequency, azimut and elevation, your chances of success are minimal.
For presetting elevation, we used the „local“ ATV repeater DB0OFG (1W, 14dBi, abt. 110km).
An ASTRA dish is almost upright (for about 32 degr. Elevation in JN49), so for 0 degr. you must tilt the dish down 32 degrees (depending on the dish, you have to modify the mounting bracket).
*Your neighbour will tell you, that your ASTRA dish is broken, but don´t worry about it.*
Initially we tried to use a SAT-FINDER as detector to optimize direction of the dish. But these gadgets are broadband, the noise in 1GHz of bandwidth is stronger than a single signal peaking out 40 dB !
If you have access to a spectrum analyzer (1...1.5GHz), it is best to use it for antenna optimizing.
You´ll be amazed „what´s in the air“ if you make a 360 degree sweep of your QTH. I have built a small module, which functions like a SAT-Finder but instead of displaying RF power on a meter, the RF is coupled to a 20dB ERA3 amplifier an fed to the spec. analyzer connector. The gain is sufficient to lift the LNC noise above analyzer noisefloor. The 10GHz amateur band is converted to 1000...1500MHz.
A LED serves as Power indicator and you can feed 12V or 18V to the module when using the LNC without a SAT-receiver. This feature is valuable for monitoring your TX, but causion: We used 2 dishes, one for RX and one for TX. The signal which came from our link partner was much stronger than our own TX signal, even though the two dishes are only 3m apart (see picture further down).
For monitoring your own Signal: Open original LNC, tune DRO down as far as possible with tuning screw.
The input filters are wide enought ! (Scematic and layout on the next page).

If you have antennas pointed, the output of the receiver is at VIDEO-OUT CYNCH or at the SCART connector.
For ATV : Just connect TV-Set....
For LINK : You first have to demodulate the 3MHz carrier (with TV you will see only fuzzy noise/moiree).
A CD4046 VCO with PLL will do the job, and you´ll have DATA at the output of the demodulator.
The channel spacing on 10GHz is 10MHz, so your modulation will not fill the entire receiver bandwidth.
The estimated 3dB to 6dB reduction in S/N should not be a problem and if it is, the link won´t be stable anyhow. (... use a larger dish ...)

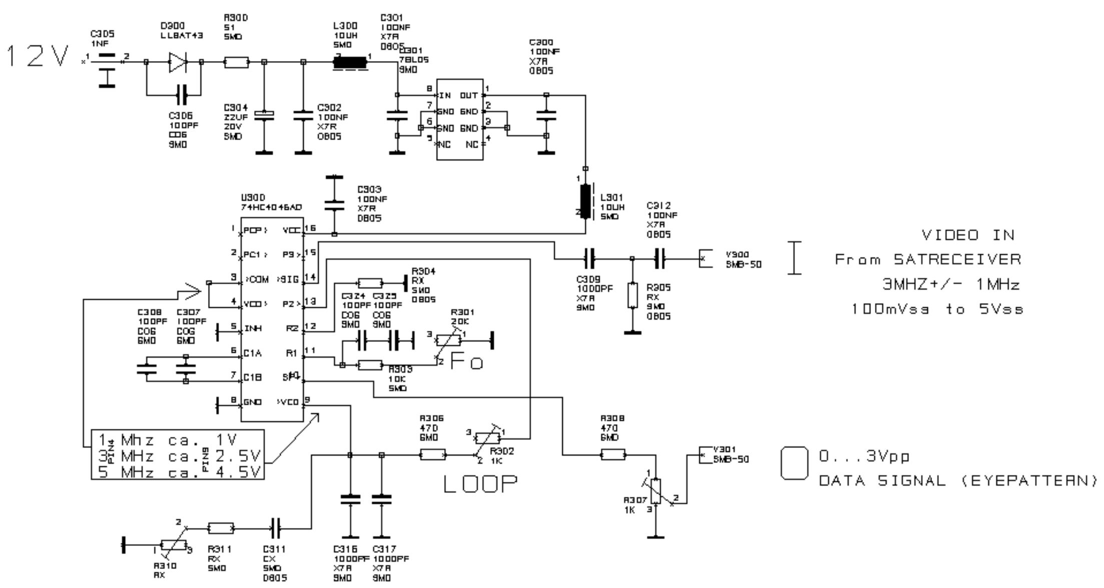







Scematic for the LNC „SNIFFER“:

Scematic of the 3Mhz demodulator:



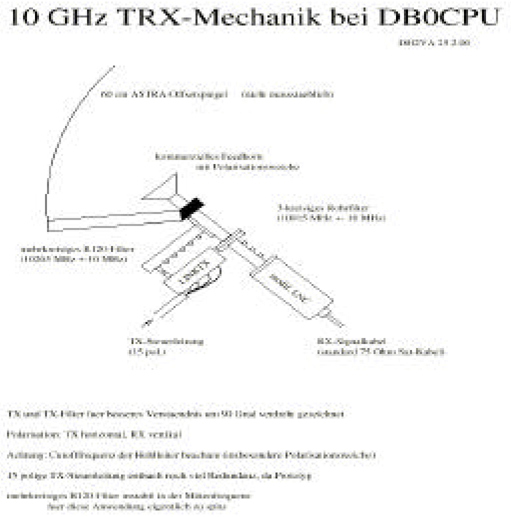
## Antennas

We have used two different ways to built the antenna system:
1 Dish or 2 Dishes
For the WPD-CPU Link (Protoype PCBs with LINK_SYN) we used both...
At DB0WPD 60cm RX and 1.2m TX.
At DB0CPU only one 60cm dish for both.

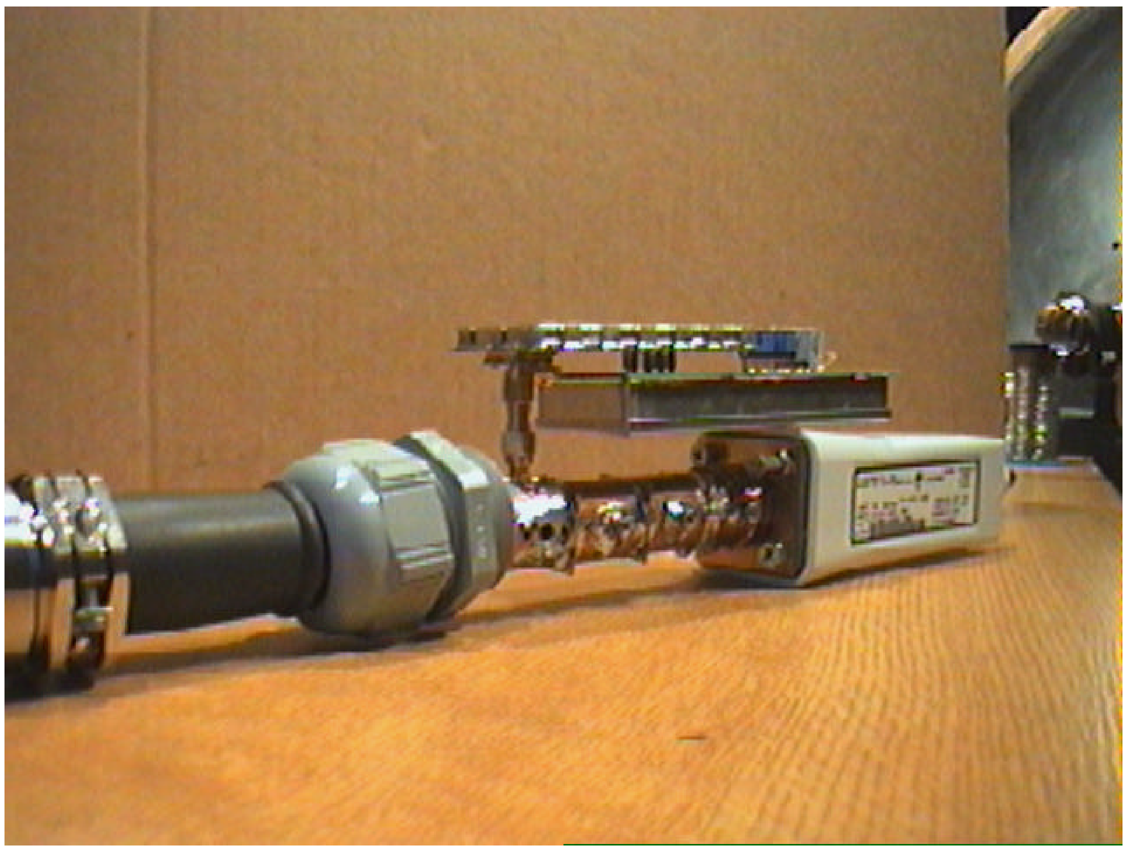
WPD side is easily explained:
The 1.2 meter TX dish was used, because it has a nice LNC weather protection (Kathrein dish).
With some pushing, the whole TX Block fitted inside the cover. The RX (ASTRA) dish was only modified for 0 degr. elevation, and the LNC was replaced with 9 GHZ LO LNC.

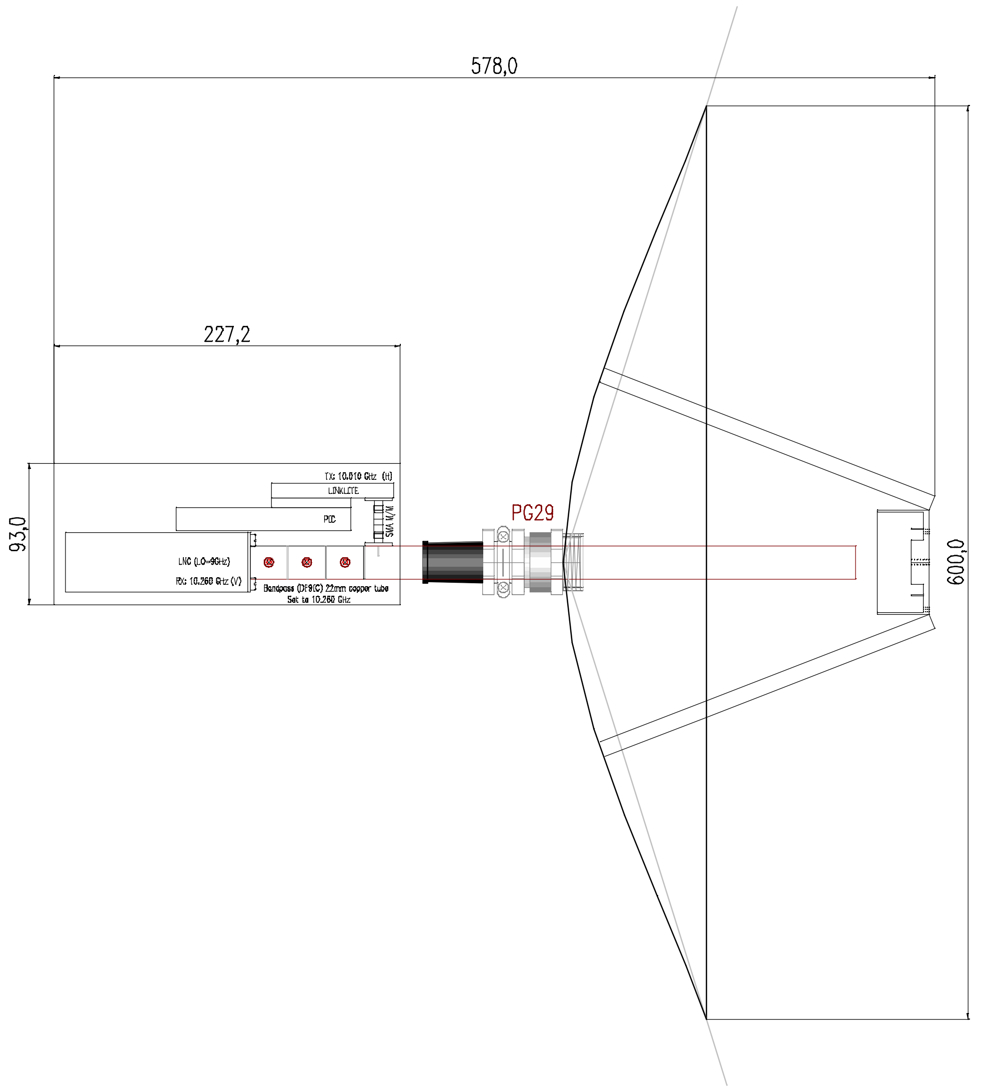
DB0CPU side:
There was only on „slot“ available on the mast.
At first we used an old ASTRA H/V splitter. But the high pass charactaristic of that thing was sharp....
10.010GHz (Weinheim TX freq.) was attenuated abt. 15dB... 10.260 passed...
How did we find out? Well a second LNC pointed towards Weinheim had only 10dB less S/N than the LNC mounted in the dish. (measured with DF7IT „LNC-SNIFFER and old HP spec-anal.“)
Since the protoype LINK_SYN only had 0.5mW at the feed, the test failed in one direction....
Replacing the H/V splitter with a larger diameter one (from FTE) solved this.
To protect the RX LNC from TX you have to use a bandpass in front of the LNC.
We used one built with 22mm copper tube published by DF9IC /4/.

The filter was fitted with two flanges and tuned by **DL3NQ**, since i have no measurment capabilty on 10GHz yet. The TX was fed also thru a bandpass. This is not necessary when you use H/V polarisation, but the filters had SMA on one side and R120 „LNC“ flange on the other.
Below is a reprint from our web page (Prototype DB0CPU setup, german).




We think about using center feed dishes 60cm (UKW-Berichte, DM20.-)
D1ieter, DL3NQ has a nice design for a subreflector so that the dish could be fed from the back side of the dish. This design is a mixture of the 10GHz DF9IC bandpass /4/, and a dual-band (10Ghz 24GHz) 22mm feed published in /5/, UKW-Berichte by DJ7FJ some years ago.
(see next page) Tests look very promising.... TX to dish seems to be only 0.5dB lower than direct coupling into SMA/R100, RX bandpass loss is less than 3dB, polarisation decoupling better than 25dB.
If you feed the TX directly into the "dish" end of the tube, you can see the noise generated from the TX at the LNC output.If you use the LNC sniffer, the RX bandpass is easily tuned !
For weather protection this block should fit into 100mm PVC tubing using standart end-plugs.



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pages 28.1 to 28.16
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/2/ Jürgen Martens, DF5TY:“High-speed PR-Interlink auf 10GHz
Seiten 15.1 bis 15.4
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/3/ Helmut Neidel, DL1IN, „ATV-Sender für 5,7 und 10GHz
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/4/ Wolf-Henning Rech, DF9IC: „Duplexweiche für 10GHz“
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/5/ Josef Fehrenbach, DJ7FJ: „Duobanderreger für 10GHz und 24GHz“
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